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Materials & Methods®

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FEATURE ARTICLES

MATERIALS & METHODS MANUAL NO. 58

ENGINEERING FILE FACTS

DEPARTMENTS

NEXT MONTH: Metal-Ceramics for High Temperature Service . . . Low Temperature and Notched Properties of Two Steels . . . Soft Grits for Blast Cleaning . . . Cold and Hot Molding Magnet Coils . . . Duroids . . . Precision Finishing Gears of Different Materials . . . SELECTION OF STAINLESS STEELS (Materials & Methods Manual No. 59)

The Materials Outlook

Apart from the recent shenanigans of the UMW and the resulting industrial curtailment, the business picture has been generally favorable, and the view ahead is almost everywhere considered good . . . at least until midsummer. . . . Trade volume is currently large; incoming business has been above par since the first of the year; and good backlogs of unfilled orders are still the rule. . . . Detroit, steel's biggest customer, would be breaking records were it not for the Chrysler shutdown. . . . G.M., Ford, and most of the lesser independents are operating at full throttle to meet expected sales waves during the next three months. . . . Biggest encouragement comes from machine tool builders' reports. . . . Recent increase in new orders boosted monthly tallies to highest peak since August 1946. . . . Significant, in that industries, while reducing plant expansion from last year's level, are replacing and modernizing on at least an equal scale. . . . All in all, the statistics make good reading. . . . The upturn in industrial output and employment which began last Summer is still going strong. . . . Primary production is outrunning consumption of finished goods in some scattered lines and inventories are climbing. . . . But, for the nonce, the skies are clear.

Titanium keeps popping up in the news with increasing frequency. . . . Latest information spotlights continuous production of titanium or titanium alloy ingots using magnesium and titanium tetrachloride as raw materials . . . method not yet fully developed; Battelle doing the work. . . . Present technique actually a two-step process . . . but will ultimately be a single integrated unit. . . . Products from reaction chamber will run continuously into an arc furnace. . . . Titanium will be melted in furnace; magnesium chloride and unreacted magnesium will be volatilized, condensed, and removed while continuously formed titanium ingot is withdrawn from bottom of furnace. . . . Purity of titanium thus produced expected to be greater than that currently resulting from batch methods.

Contributing to the overall impression of relatively smooth sailing during the months ahead is the materially improved volume of steel casting production . . . and the attendant prospect of increased manufacturing operation. . . . This optimistic view is engendered principally by the revival of advance orders for railway equipment, normally a comparatively heavy percentage of the industry's tonnage.

Despite the current interest focussed in steel, copper, aluminum and other standard metals, don't overlook the strides made by lesser-known alloys. . . . Typical of these are the iron-nickel specialties. . . . These contain 22 to 80% nickel and have many diverse physicals. . . . Useful in instruments, controlling machines, and processing equipment as well as in radar, electronic and telephone apparatus. . . . Permanent magnets of Alnico, widely used in industry, have now entered the home. . . . Used for can openers, children's toys, and shower curtain retainers. . . . And while on the subject of iron-nickel alloys, it is of interest to note that the use of wood is slowly giving way to Inconel (a nickel-chromium-iron alloy)

(Continued on page 4)

The Materials Outlook *(Continued)*

in vineyard equipment in contact with one of the best French vermouths.

Plastics consumption jumped to a record high last year; 18% over the 1948 level and more than 50% over 1946, the year when war-time restrictions on commercial applications were lifted. . . . Styrene and vinyl are the contenders for leading volume honors; together they accounted for almost half of last year's consumption. . . . Production of thermoplastic molding materials rose 42% over 1948 . . . but thermosetting compounds dropped 29%. . . . This could portend a significant trend for future product applications.

Molybdenum, long used for high temperature materials applications, enters a relatively new field of use: Lubrication. . . . New molybdenum-base lubricant can be used alone or added to other oils. . . . Provides a low-friction, anti-seizing coating to bearing surfaces. . . . Material has unusual chemical stability; is unchanged in its properties by extremes of temperatures: operates effectively at either sub-zero or red-heat. . . . Typical uses, aside from conventional bearing and gear applications, include lubrication of deep-drawing dies where it is claimed to eliminate hand-working of high spots and prevent metal pull out, as a pipe-fitting compound, and for press-fit work.

Insuring better gray iron, a new ferro vanadium alloy having 7 to 11% silicon with a carbon content of about 1% results in much more rapid solution than heretofore and completely eliminates hard spots caused by undissolved alloy. . . . Vanadium content ranges from 38 to 42%. . . . High specific gravity of alloy reduces tendency to float, in contrast to alloys higher in vanadium with equal or higher silicon content. . . . Cold additions of as much as 0.40% vanadium to the ladle are easily dissolved and controlled. . . . Should portend even greater advances in the use of gray irons . . . materials, which contrary to opinion in some quarters, are far from obsolete yet.

Aluminum output is moving into high gear to meet the unprecedented demand for the light metal. . . . Orders are continuously pouring in, according to industry spokesmen, and the producers expect to operate primary facilities at peak levels at least until late summer. . . . Contributing to the demand is the addition of aluminum to the Government stockpiles of strategic materials. . . . Not to mention the rapidly expanding list of uses which apparently grows daily as more and more manufacturers redesign their products to take advantage of the light metal's characteristics.

And speaking of aluminum. . . . Current production of primary metal reflects continuing upward trend which began last fall. . . . New production facilities now being added throughout the industry to boost capacity for future operations. . . . Cases in point: Reactivation of idle potline by Reynolds at its Jones Mills, Ark. reduction plant. . . . New reduction works at Port Lavaca, Tex. being built by Alcoa which is, incidentally, the first facility for making primary aluminum built since end of war.

Newest wrinkle emanating from the Naval Engineering Experiment Station at Annapolis is the use of an "oil-powder" to detect surface flaws and cracks in metals. . . . Film of penetrating oil is first applied to surface being inspected, then removed. . . . Area is dusted with nonabrasive detecting powder. . . . Defects show up in red against a white background. . . . Biggest advantage is the speed. . . . Should prove useful in industrial operations.

PREVIEW

Sixth Annual Metal Powder Show and Meeting

The Sixth Annual Metal Powder Show and Meeting will be held on April 25-26 in Detroit, Mich., at the Book-Cadillac Hotel. The Show, sponsored by the Metal Powder Association, is open to everyone interested in powder metallurgy and will include a technical program as well as exhibits by leading producers and manufacturers in the powder metallurgy field.

The technical program will stress the engineering and business aspects of the industry. Among the subjects to be covered are descriptions of two new metal powders, the uses of metal powder parts in the radio and television industry, and a report on the outlook for powder metallurgy in various fields. In addition, one entire session will be devoted to the popular informal type of session at which practically any subject concerned with powder metallurgy can be discussed. All technical sessions will be held in the Crystal Ballroom, Book-Cadillac Hotel.

Displays of the latest advances and developments in the industry will include those of powder producers, metal powder parts fabricators, and equipment manufacturers. The exhibits will be shown in the Italian Garden (Book-Cadillac Hotel) from 9:00 A.M. to 7:00 P.M. on Tuesday and 9:00 A.M. to 5:00 P.M. on Wednesday.

List of Exhibitors

Exhibitor	*Booth No.*
Amplex Div., Chrysler Corp.	2, 3
Antara Products Div., General Aniline & Film Corp.	12
Arthur Colton Co., Div. of Snyder Tool & Engineering Co.	5
Dale Corp.	23
Ekstrand & Tholand, Inc.	26
Electric Furnace Co.	4
Federal-Mogul Corp.	18
Charles Hardy, Inc.	19
Harper Electric Furnace Co.	22
Kux Machine Co.	1
Lindberg Engineering Co.	10
Materials & Methods	6
Metals Disintegrating Co.	13, 14
Metals Refining Co.	16
New Jersey Zinc Co.	25
Plastics Metals Div., National Radiator Co.	21
Powdered Metal Products Corp. of America	7
Product Engineering and American Machinist	9
Raybestos Div., Raybestos-Manhattan, Inc.	17
Reinhold Publishing Corp.	6
F. J. Stokes Machine Co.	11, 20
S. K. Wellman Co.	15
The Wel-Met Co.	24
Western Gold & Platinum Works	8

Program

Tuesday, April 25

MORNING

10:00 A.M. *Informal Open Discussion of Powder Metallurgy—Discussion Leaders: Fred P. Peters, Vice President, Reinhold Publishing Corp. and Editorial Director,* MATERIALS & METHODS, *and T. L. Robinson, President, Wel-Met Co.*

AFTERNOON

2:15 P.M. *Welcome by the President, B. T. du Pont, Sales Manager, Plastic Metals Div., National Radiator Co., and Introduction of Program Chairman, T. R. Moore, Sales Manager, Antara Products Div. of General Aniline & Film Corp.*

2:30 P.M. *Thermo Chemical Coated Metal Powders—J. E. Drapeau, Jr., Technical Director, Metals Refining Co., Div. of the Glidden Co.*

3:15 P.M. *Cost Accounting, with Reference to Powder Metallurgy Products—A. J. Langhammer, President, Amplex Manufacturing Co., Subsidiary of Chrysler Corp.*

4:00 P.M. *Application of Iron Powder in Radio and Television Circuits—F. E. Edwards, Chief Engineer, Standard Coil Products Co., Inc.*

5:30 P.M. *Reception—Cocktails and Buffet—Grand Ballroom*

Wednesday, April 26

MORNING

10:00 A.M. *A New Type of Stainless Steel Powder—George Stern, Director of Research, American Electro Metal Corp.*

10:45 A.M. *The Use of Metal Powder Parts as Friction Materials—Francis Lowey, S. K. Wellman Co.*

11:30 A.M. *Metal Powders in a Competitive Market—John Sasso, Industrial Production Editor, "Business Week"*

AFTERNOON

1:00 P.M. *Luncheon—Grand Ballroom*

News Digest

AIME Papers Cover Progress in Titanium, Other Materials

About 290 technical papers were presented at the annual meeting of the American Institute of Mining & Metallurgical Engineers held in February in New York City. Those papers believed to be of most interest from a materials viewpoint have been briefly summarized below.

Titanium Binary Alloys

Three comprehensive reports on titanium alloys were presented by C. M. Craighead, O. W. Simmons and L. W. Eastwood of Battelle Memorial Institute. In the first of these papers, entitled "Titanium Binary Alloys," the authors reported on binary alloys of titanium with silver, lead, tin, copper, beryllium, boron, silicon, chromium, molybdenum, manganese, vanadium, iron and cobalt.

One-half-pound ingots of the alloys were prepared in an arc furnace, employing a water-cooled copper crucible, an argon atmosphere and a water-cooled tungsten electrode. The half-pound ingots were fabricated by forging at 1700 F in air down to a ¼-in. slab, followed by hot rolling at 1450 F down to 0.060-in. sheet. Tensile properties, minimum bend radii, hardnesses, response to heat treatment and aging treatment, and phase relationships were determined for these alloys.

Although the range of composition of alloys containing silver, lead, tin or nickel was not adequate, the limited data are sufficient to show that silver, lead and tin do not produce binary alloys with high tensile properties. Beryllium, boron and silicon all have extremely limited solubility in alpha and beta titanium and are not useful as major alloying elements, although they may be useful as minor additions in complex alloys. Manganese, chromium, molybdenum, vanadium, iron, cobalt and copper all produced binary alloys with fairly high tensile properties. Of these, the first three are best and copper definitely the poorest.

Unalloyed titanium and practically all of the binary alloys are increased in hardness when quenched from elevated temperatures, the increase being greater the higher the temperature, at least up to 1750 F. Several of the binary systems age harden slightly after quenching from a high temperature and even in the hot-rolled condition.

The available data indicate that the best properties of titanium alloys are obtained in the as-hot-rolled condition, though no data are presented on the alloys aged after hot rolling. Annealing produces slightly lower tensile strength with only a slight increase in ductility. Although the data are limited, cold working the annealed alloys does not appear to be beneficial since the loss in ductility is accompanied by only a slight increase in tensile stress.

Titanium Ternary Alloys

The Battelle investigators extended their studies to 113 ternary titanium-base alloys, reporting their results in "Ternary Alloys of Titanium." The compositions investigated are as follows:

1. Titanium-carbon alloys containing copper, silicon, vanadium, chromium, manganese, iron or cobalt.
2. Titanium-nitrogen alloys containing chromium.
3. Titanium-chromium alloys containing additions of vanadium, molybdenum, tungsten, cobalt or nickel.
4. Titanium-manganese alloys containing additions of silicon, chromium, tungsten or iron.

In general, the addition of 0.25% carbon in the ternary alloys produces some improvement in the tensile strength of the as-hot-rolled alloys without a serious sacrifice in ductility. At 5 manganese and 0.25% carbon, tensile strength of 190,000 psi. and 4% elongation are obtained in the as-hot-rolled condition. Additions of 0.1 to 0.2% nitrogen to titanium-chromium alloys increases the hardness and strength but slightly lowers the ductility of the as-hot-rolled alloys. At 5 chromium and 0.1% nitrogen, 186,800 psi. tensile strength, 5% elongation in 1 in., 295 Vickers hardness and 3t minimum bend radius are obtained. The 5 chromium-0.2% nitrogen alloy in the as-hot-rolled condition increases in hardness when aged at 750 F.

Additions of vanadium, molybdenum, tungsten, cobalt or nickel to titanium-chromium alloys are generally not beneficial. The titanium-chromium-cobalt alloys in the as-hot-rolled condition age harden appreciably at 750 F.

Of the elements introduced into titanium-manganese alloys, silicon appears to be definitely detrimental. Iron increases strength considerably but with a sacrifice in ductility. Chromium additions here have little effect on tensile properties, but 1% tungsten may be useful. An alloy containing 5 manganese and 1% tungsten produces 190,000 psi. tensile strength,

(Continued on page 49)

News Digest

Fluoborate Electrolyte Offers Strong, Ductile Nickel Plate

The use of fluoborates as an ingredient in nickel plating baths is not new but, up to this time, little data have been available on the behavior of electrolytes having nickel fluoborate as the major source of nickel ions. A recent investigation by E. J. Roehl and W. A. Wesley, however, has shown that the high ductility and low stress of deposits from the fluoborate bath, together with its well known high buffing capacity and its good conductivity, make the bath attractive for rapid plating of heavy deposits. Their research was published in *Plating* (February).

High Mechanical Properties

The results showed that a good general-purpose bath is one containing 40 oz. per gal. nickel fluoborate and 4 oz. per gal. excess boric acid operated at 2.7 to 3.5 pH and a temperature of 130 F. At 50-amp. per sq. ft. current density, deposits from this bath have a hardness of 130 Vickers, tensile strength of 55,000 psi. and elongation of 32% in 2 in. The residual contractile stress in fluoborate deposits was found to be only about two-thirds of that in nickel from the Watts bath plated under comparable conditions. Good adhesion of nickel to steel and copper surfaces is readily obtained.

The tendency to form trees on heavy deposits is less than with a Watts bath but greater than in the chloride bath. The tolerance for impurities seems to be about the same as for the Watts and chloride baths; in all three baths iron causes an increase in contractile stress.

Anode and cathode efficiencies at current densities up to 100 amp. per sq. ft. are high, not much different from those in the Watts bath. The fluoborate bath is a high-conductivity bath, comparable to the all-chloride electrolyte in this respect.

Corrosion Presents Problem

Producers of nickel fluoborate do not recommend use of lead or high-silicon cast iron in contact with the fluoborate bath. Although this limits the usefulness of the bath, rubber, pyrex glass, carbon and certain corrosion resistant steels are said to be satisfactory.

The authors of this paper conclude that, in spite of the high cost of the principal ingredient, the fluoborate bath should be considered whenever an easily controlled process is desired for making moderately stressed ductile nickel deposits at a rapid rate.

Dr. H. W. Gillett

Dr. Horace W. Gillett, 66, former editorial director of MATERIALS & METHOD'S predecessor—*Metals and Alloys*—died March 3 from a heart attack near Nicholasville, Ky. Technical consultant to Battelle Memorial Institute at the time of his death, Dr. Gillett was returning to his home in Columbus, Ohio, after a Southern hunting trip.

Dr. Gillett was internationally known as an authority on metallurgy and was often called the dean of American metallurgy. He was responsible for the technical organization of Battelle Memorial Institute, and served as its first director. He was also the inventor of numerous metallurgical processes and author of scores of books and articles on scientific subjects.

He was the first editorial director of this publication. During the 13 years in which he guided the editorial policies of this paper, he examined and approved all published feature material and wrote many articles, extended abstracts and correlated abstracts, but readers will most likely remember him for his pointed, logical and witty editorials on the problems facing the metal industries. Dr. Gillett possessed a powerful and pungent pen, an uncommon amount of common sense, and a rugged independence of both political and technical thought and writing.

He was one of those who aggressively pioneered the idea of placing the growing science of metallurgy on an engineering basis. Although he greatly respected the technical and scientific leaders in his field, especially those who had actually made distinguished contributions to its knowledge, he never under-rated the importance of the younger men in the field and continually encouraged them to present their ideas and to seek recognition for the good work they did.

Horace Wadsworth Gillett was born in Steuben County, N. Y., Dec. 12, 1883. He received his A.B. degree in chemistry from Cornell University in 1906 and his doctorate in 1910. In that year he was made manager of the research department of Aluminum Castings Co. in Detroit. In 1912 he became associated with the U. S. Bureau of Mines as an alloy chemist, and 12 years later was appointed chief of the Division of Metallurgy, U. S. Bureau of Standards. In 1929, Dr. Gillett was chosen to head the newly founded Battelle Memorial Institute, and in the same year he became editorial director of *Metals and Alloys*.

By inclination a scientist, rather than an administrator, Dr. Gillett resigned his Battelle directorship in 1934, assuming the position of chief technical advisor. In 1942, he relinquished his direction of *Metals and Alloys* to serve on the Advisory Committee on Metals and Minerals to the War Production Board and as a member of the Research Division of the War Metallurgy Committee. He retired as Battelle's chief technical advisor in early 1949 and since had been serving as a technical consultant to the Institute.

continued from page 47

4.5% elongation in 1 in., 337 Vickers hardness number and 3t minimum bend radius. This alloy in the as-hot-rolled condition appears to age harden.

In the higher alloy ranges, many of the ternary alloys studied increase in hardness when they are quenched from the beta-phase field. The hardness increase obtained by water quenching from 1600 F is accompanied by a loss in ductility. Since hardening occurs by quenching from or near the beta field, the authors expect that useful heat treatments may be developed.

Titanium Quaternary Alloys

The third and last of this series of papers was entitled "Quaternary Alloys of Titanium" and covered 84 alloys from the following systems:

1. Titanium-chromium-carbon-nitrogen.
2. Titanium-chromium-carbon with copper, vanadium, molybdenum, manganese, iron or nickel.
3. Titanium-chromium-nitrogen alloys containing vanadium, molybdenum or nickel.

All of the alloys are increased in hardness by quenching from the beta field, but the tensile properties of none are beneficially affected by quenching in water from 1600 F. Since hardening by quenching from

Nominal Composition, %	Ult. Ten. Str., Psi.	Elong., % in 1 In.
3.5 Cr, 0.25 C, 0.1 N	163,200	7.0
5.0 Cr, 0.25 C, 0.1 N	183,200	6.0
5.0 Cr, 1.0 V, 0.25 C	171,900	5.0
5.0 Cr, 2.0 V, 0.25 C	189,700	3.5
3.5 Cr, 1.0 Mn, 0.25 C	162,400	4.5
5.0 Cr, 1.0 Mn, 0.25 C	177,200	4.5
3.5 Cr, 2.0 Mn, 0.25 C	137,800	9.5
5.0 Cr, 2.0 Mn, 0.25 C	194,400	2.0
3.5 Cr, 2.0 Fe, 0.25 C	190,700	6.0
3.5 Cr, 2.0 V, 0.2 N	177,200	6.0
5.0 Cr, 1.0 Mo, 0.1 N	175,000	4.5
3.5 Cr, 1.0 Mo, 0.2 N	190,000	7.0
5.0 Cr, 1.0 Ni, 0.1 N	182,000	5.0
5.0 Cr, 2.0 Ni, 0.2 N	194,700	3.0

a temperature in or near the beta field is quite marked, however, the authors believe useful heat treatments may be developed after further investigation. Most of these titanium-chromium alloys, particularly those containing 3.5 and 5% chromium, age-harden appreciably in the as-hot-rolled condition when subjected to an aging treatment consisting of 4 hr. at 750 F.

Several of the best quaternary alloys and their strength and ductility properties are listed in the accompanying table. As yet no corrosion data are available for any of these titanium alloys.

In the discussion following presentation of these papers, the Battelle investigators revealed that they are currently developing a titanium alloy expected to have about 200,000 psi. tensile strength, 185,000 psi. yield strength, 7% elongation and 0.165 lb. per cu. in. density. The alloy will contain approximately 3% chromium plus other elements. On the basis of strength-weight ratios, the Battelle works say such an alloy will be superior to the most highly alloyed steels now known.

Other Titanium Papers

A basic study of the "Effects of Three Interstitial Solutes (Nitrogen, Oxygen and Carbon) on the Mechanical Properties of High-Purity, Alpha Titanium" was reported by Walter L. Finlay and John A. Snyder of Remington Arms Co., Inc. These effects were determined on fusion-alloyed, annealed specimens in comparison with a substitutional solute, iron. A good correlation between bend ductility as well as the several micro-tensile properties was established for both the binary and ternary alloys of the interstitial solutes. Moreover, in

(Continued on page 122)

News Digest

Working Together for

Faster Steel Service

Here's the team that swings into action the moment you contact a Ryerson plant. From the phone girl who receives your call to the driver who delivers your order it's a team of specialists who take pride in the job of getting steel to you quickly.

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Nodular Gray Iron Compared with Other Cast Ferrous Metals

A realistic evaluation of these new irons, variously known as ductile, spheroidal or nodular iron, indicates that they have a wide range of potential engineering applications and in many cases can compete with steel and malleable castings.

by G. VENNERHOLM, H. BOGART and R. MELMOTH, Ford Motor Co.

• GRAY CAST IRON with its free graphite flakes in a steel matrix is well known for its high resistance to mechanical wear and heat checking, excellent damping qualities and superior machinability. These properties, depending upon the discontinuity of structure produced by the graphite particles, are achieved, however, at a sacrifice of strength and ductility, thereby limiting applications of this material to relatively low stressed parts. The greater the structural discontinuity produced by large flaky graphite, the more pronounced is the adverse effect on strength and ductility. Obviously, the smallest loss in physical properties will result from a graphite that is present in a finely dispersed, well-rounded particle.

In view of this, it is of significant interest to both the engineer and metallurgist that research conducted both in this country and abroad has resulted in ways and means of producing a rounded graphite particle in the as-cast condition. Further than that, this graphite particle does not seem to be an aggregate of fine flakes, but a true carbon crystal body or "spherulite." Although the information generally available so far is rather limited, indications are that these irons have a wide range of potential engineering applications. We will, for the sake of simplicity, refer to this material as nodular graphite iron or nodular iron as distinguished from flake graphite iron.

It is the purpose of this article to attempt a realistic evaluation of the present status of the development. As relatively few opportunities have presented themselves to compare notes with other investigators, most of the data is based on results obtained in our own research laboratories and foundry facilities.

Production of Nodular Iron

The production of nodular iron, as is now well known, is generally accomplished by a two-stage operation. The first stage is that of the addition of a small amount of cerium, magnesium, lithium, or similar carbide formers which promote the formation of white iron in an iron normally solidifying gray. The second stage is an opposing stage in which a ferrosilicon type of inoculant overcomes the tendency toward white iron, causing the graphite to precipitate out in the form of small spherulites. In general, it can be stated that any iron which, including its ferrosilicon inoculant, solidifies gray can be made nodular by treatment with magnesium.

The choice of the carbide stabilizing agent is governed by economic considerations which seem to favor the use of magnesium. In addition, limitations surrounding cerium and some of the other metals, such as the requirement that the iron in question be hypereutectic, do not apply to magnesium. The magnesium can be introduced as a relatively pure metal, as a nonferrous alloy including magnesium, or as a ferrosilicon modified with magnesium. It is obvious that with a boiling point of around 2030 F, pure magnesium becomes gaseous at molten iron temperatures and reacts with explosive force in the presence of air. Similarly, the magnesium-rich alloys are more violent than those containing smaller amounts of magnesium. It has been found that the recovery of magnesium in the iron is inversely proportional to the concentration of the alloy.

Numerous alloys have been investigated but most of these have been discarded in favor of magnesium-nickel, magnesium-copper, and of late, magnesium-copper-ferrosilicon. The latter is of particular interest in that this alloy does not involve addition of large amounts of nickel or copper.

The relative amount of magnesium required to produce nodular iron depends upon the amount of sulfur present in that the first reaction following the addition appears to be the formation of magnesium sulfide, thereby removing the sulfur from the field of action. This reaction proceeds until the sulfur analysis approximates 0.02%, at which point the magnesium becomes effective in changing the form of the graphite.

Experience has shown that a minimum of 0.035% magnesium must be present in order to effectively pro-

Table I—
Relative Efficiency and Cost of Magnesium Addition Agents

(Based on Treatment of 0.03% S Iron at 2700 F to Give 0.08% Residual Magnesium)

Alloy	Mg Addition	% Mg Recovery	Alloy Wt. Ton	Alloy Cost[3] Ton Melt
6% Mg-10% Cu-Fe-Si[1]	0.3%	32%	100 lb.	$15.00
13% Mg-10% Cu-Fe-Si[1]	0.4%	24%	61 lb.	$10.40
20% Mg-80% Cu[1]	0.53%	19%	53 lb.	$21.20
50% Mg-50% Cu[2]	0.7%	14%	28 lb.	$11.20

[1] *Added to stream at 2700 F.*
[2] *Added to covered ladle at 2700 F.*
[3] *Assuming cost of*
6% alloy .... $.15/lb.
13% alloy .... $.17/lb.
20 and 50% alloys .. $.40/lb.

duce completely nodular iron in a typical cupola analysis. If the recovery exceeds 0.1% magnesium, however, excessive carbide stabilization occurs, ultimately resulting in a stable white iron. Table 1 shows the approximate recovery in per cent that can be expected for various magnesium-copper and magnesium-copper-silicon alloys when added to an iron containing 0.03% sulfur in amounts sufficient to produce nodular iron. It must be understood that these figures are representative only of the particular practice and analysis range peculiar to our experimental work and should not be treated as a yardstick. Efficiency of magnesium recovery is influenced by several factors which must be carefully controlled if consistent results are to be expected. The actual amounts of the various alloys shown in Table 1 required to treat an 0.03% sulfur iron at 2700 F so as to recover 0.08% magnesium and the anticipated cost of magnesium treatment are also shown.

The selection of the most practical magnesium addition agent must be predicated on a proper balance between reproducibility in results, efficiency of magnesium recovery, influence of carrier metal on base analysis, amount of pyrotechnics consistent with safe practice, slag forming tendency and chilling effect.

At the present time, our experience indicates that the magnesium-copper-ferrosilicon alloys meet most of the requirements mentioned. It is of interest to note that in the initial experiments with magnesium-ferrosilicon alloys, the reaction proceeded spasmodically with an appreciable amount of spatter and produced a crusty slag. With the addition of copper to these alloys, the spatter was eliminated and the slag became much more workable. The rapid progress being made in alloy development suggests that new alloys and new techniques of addition will soon appear and obsolete our present thinking.

The temperature of the molten iron has a considerable bearing on the relative magnesium recovery and, consequently, on the economy of the operation. The lower the temperature consistent with safe operation, the greater is the recovery. Whereas in Table 1 the recovery from a 6% magnesium-copper-ferrosilicon alloy is about 32% at 2700 F, the expected recovery at 2500 F, could such a temperature be used safely, is approximately 45%. The chilling effect of the magnesium alloy and the inoculant necessitates treating the base metal at a considerably higher temperature than that required for the satisfactory pouring of the casting (approximately 150 F in the case of the 6% magnesium alloy).

This would seem to favor the magnesium-rich alloys such as 50% magnesium—50% copper, where smaller quantities of the carrier element are required. The increased volatility of these alloys, however, with the resultant safety hazard, more than offsets this advantage, nor does their use appear to be justified on a basis of cost.

The source of the molten metal, be it blast furnace, cupola or electric furnace, does not seem to have any appreciable influence on the casting or engineering properties of the nodular iron family. This is not to say that the properties are independent of the chemistry, for we must emphasize that definite chemical limitations exist, especially in the manufacture of the more ductile forms of iron.

Relatively few foundries have any choice in the matter of melting equipment as the large majority, especially in the gray iron industry, are equipped only with cupolas. The appreciable sulfur pick-up associated with cupola operations is a distinct disadvantage in that most of this sulfur must be eliminated before the magnesium treatment becomes effective in reshaping the graphite. This can be done either by conventional desulfurizing methods or the use of additional amounts of magnesium alloy over and above that required for carbide stabilization. The cost of such treatments is an appreciable factor which cannot be overlooked. Those foundries which are equipped with electric furnaces may find it advantageous to use these units instead, as then a base iron of initially low sulfur at controlled temperatures can be produced, thereby minimizing the amount of magnesium alloy required.

Regardless of which unit is selected for the manufacture of nodular iron, a thorough understanding of the effect of the various elements on resultant properties is necessary in order to determine the proper chemistry to meet physical requirements.

If the emphasis is on high strength with ductility as a secondary factor, a conventional cupola iron can be treated. The microstructure of such an iron, as indicated in Fig. 1, is composed of a lamellar pearlitic matrix with spherulites interspersed. Should the emphasis, however, be on high ductility and resistance to impact (as cast), the effect of manganese and phosphorus and, to a lesser extent, silicon and carbon must be carefully considered.

Manganese adversely affects the ductility and should, therefore, be kept as low as economic considerations permit, preferably around 0.15% and not over 0.30%. Phosphorus, as is well known, has a pronounced embrittling effect and must not exceed 0.04% for maximum ductility and impact.

Although high silicon and high carbon are desirable in that they promote ferrite precipitation and, consequently, produce irons of maximum ductility, it must be borne in mind that amounts of silicon in excess of 3% begin to harden the ferrite with resultant decrease in ductility. Similarly, high carbon contents tend to produce more and usually larger nodules and, as a result, decrease strength, ductility and modulus of elasticity. Maximum ductility is, therefore, affected through a proper balance of these various elements. The microstructure of such an iron, as shown in Fig. 2, is composed of a lamellar pearlitic matrix with large bull's-eye ferrite surrounding each spherulite.

Heat Treatment and Section Size

Nothing has been said up to now

about the response of these irons to heat treatment. The very nature of the as-cast structures, however, suggests that they will respond in a manner similar to cast iron and malleable. Numerous tests have shown this to be the case, thereby further broadening the potential field of applications.

It must be remembered that we are dealing with two distinct materials which, as a result of relatively small differences in chemistry, exhibit decidedly different degrees of ductility in the as-cast condition. This is clearly demonstrated in Table II, which also shows the effect of section size on physical properties in the as-cast, annealed, and quenched and tempered condition. It must be pointed out that the magnesium addition selected for this test was based on 2-in. cross section in order to demonstrate the relationship between section size and the amount of magnesium required. An examination of the microstructures shows that the loss in properties in the heavier sections is, to a large extent, a result of insufficient amounts of magnesium. It is of interest to note that the presence of the higher manganese content in the high strength iron appears to augment the magnesium. The selection of the proper amount of magnesium for a given size casting, therefore, must be predicated on the average casting size in order to obtain completely nodular graphite in the heavy section without inducing excessive chill in the lightest section.

In the interest of practical heat treat applications, the 2-hr. treatment at 1320 F in Table II producing an iron with an elongation of about 17% and a Brinell hardness of 163 is compared with the longer treatment of 1750 F for 2 hr., furnace cooling at a controlled rate to 1200 F, resulting in an elongation of 19% and a Brinell hardness of 148. Much higher ductilities, such as 25 to 28% have been reported by some investigators, but these can only be achieved by long heat treat cycles, which seem a bit impractical except in specific cases where the properties developed can be fully utilized.

The response of nodular irons to hardening treatments, either local or full, is good. By oil quenching from 1550 F and tempering, properties as indicated in Table II can be readily attained. Some typical microstructures resulting from these various treatments are shown in accompanying photomicrographs.

Nodular cast irons of normal gray iron compositions are more susceptible to chill in light sections than in the base metal. It has been our experience that it is difficult to avoid chilling in sections less than 3/16 in. unless a high silicon iron is used with the resultant detrimental effect on physical and other properties.

The effect of section size on the uniformity of physical properties is not noticeable in cross sections up to about 4 in. Above this thickness the ductility falls off rapidly and continues to do so but at a decreasing rate as the section size is further increased. This is true not only in the as-cast but also in the heat treated condition.

Other Properties

Castability—The fluidity of properly treated nodular irons compares favorably with that of the base iron at the same temperature. Occurrence of persistent oxide films on the surface of the treated metal cannot be minimized, as the surface condition is a direct function of the magnesium residual. The gating and risering technique, because of the high liquid shrinkage, becomes a compromise between cast iron and steel. Pattern shrinkage depends somewhat upon the base iron, whether high or low carbon, but in general is 1/16 to ⅛ in. per ft.

Machinability—The statement has frequently been made that the machinability of nodular iron is much better than that of conventional cast iron. Such a statement is apt to be misleading unless it is explained that the comparison is predicated on materials of similar physical properties. When such is the case, it is true that nodular irons machine better than flake irons. As the latter, however, are generally used in a hardness range of from about 167 to 248 Brinell as against 228 to 300 Brinell for nodular irons in the as-cast condition, any statement not clarified might be misunderstood.

We are, at the present, in the process of establishing the true machinability relationship between nodular iron and other graphitic materials. Although this work is far from complete, some basic machining data shown in accompanying charts may be of interest.

Wear Resistance—The resistance of nodular irons to lubricated wear is excellent, particularly in the absence of any free ferrite, and compares very well with gray cast iron. Although

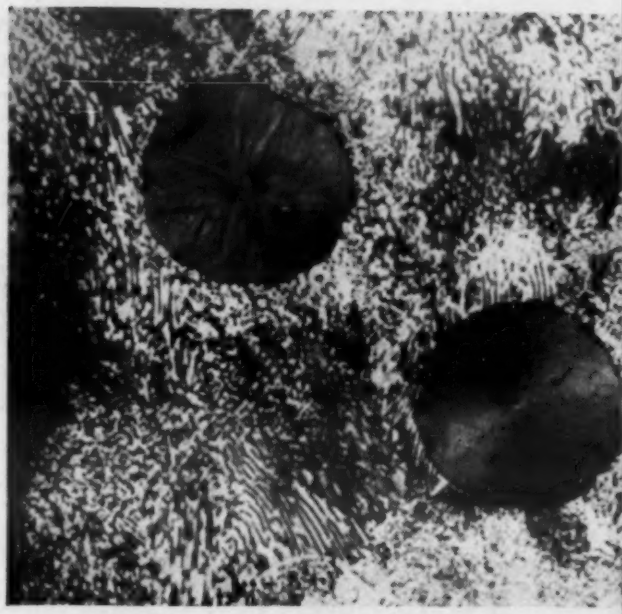


Fig. 1—Microstructure of high strength type nodular gray iron.

Fig. 2—Microstructure of high ductility type nodular gray iron.

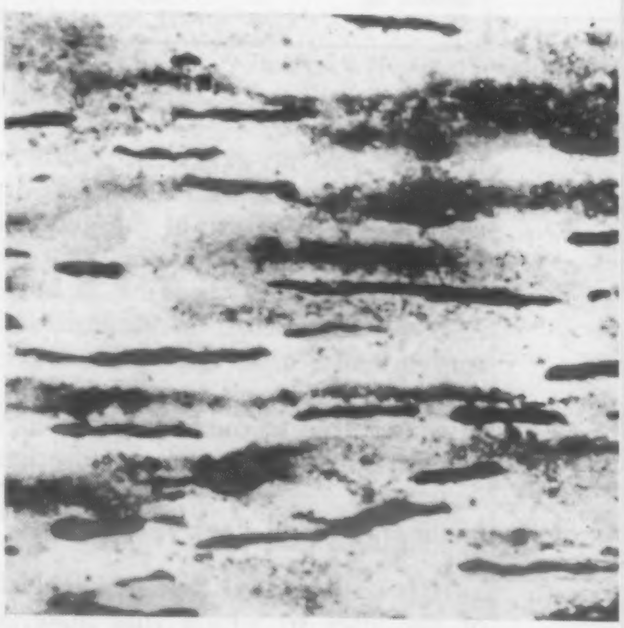


Fig. 3—There is some evidence that nodular iron can be worked around 1750 F with good results. Shown here is the structure of hot worked material.

Table II—Influence of Section Size and Thermal Treatment on Nodular Irons

Thermal Treatment	Sect. Thick., In.	Y.P. Psi.	T.S. Psi.	Elon. % 2 In.	R.A. %	B.H.	M.E. $x10^6$	Impact Ft.-Lb. (0.798-In. Dia.)
High Strength								
As-Cast	1	67,500	87,200	1.5	0	269	23.0	39
	2	67,000	80,800	1.2	0.5	262	23.0	—
	4	63,100	70,700	1.2	1.0	241	23.6	—
	6	59,800	65,200	1.2	0	229	22.7	—
	8	59,000	61,400	1.2	0.5	229	23.5	—
Anneal 1320 F 2 Hr., Air Cool	1	61,500	85,400	3.0	2.5	229	22.8	183
	2	56,600	74,700	3.2	2.2	197	21.5	—
	4	55,200	69,200	2.0	1.5	197	23.6	—
	6	57,500	65,900	2.0	1.0	217	22.2	—
	8	54,500	62,500	1.5	1.0	212	22.8	—
Anneal 1750 F 2 Hr., Slow Cool	1	51,200	78,700	7.0	4.5	187	22.4	—
	2	50,800	71,600	8.0	5.5	179	21.7	—
	4	50,200	69,800	3.5	2.5	183	23.1	—
	6	50,700	66,400	3.0	2.0	183	22.4	—
	8	50,200	66,800	4.0	2.8	183	22.3	—
1550 F 1 Hr. Oil Quench Draw 2 Hr. to Brinell as Shown.	1	95,200	104,100	3.0	3.0	269	21.9	—
	2	94,500	99,800	3.2	2.5	269	22.5	—
	4	89,100	89,700	1.8	1.5	262	21.9	—
	6	88,200	89,700	1.5	1.2	255	23.1	—
	8	85,500	86,300	1.0	1.0	255	22.8	—
High Ductility								
As-Cast	1	52,800	74,700	11.0	8.8	187	22.1	50
	2	52,200	71,800	7.5	7.5	187	22.3	—
	4	40,000	50,900	2.0	1.8	175	19.7	—
	6	37,800	45,200	3.0	1.2	148	18.8	—
	8	31,400	41,000	2.5	1.0	141	17.4	—
Anneal 1320 F 2 Hr., Air Cool	1	48,900	66,200	17.2	15.0	163	22.2	260
	2	47,500	63,300	12.5	11.0	163	21.9	—
	4	36,800	48,200	4.5	3.0	148	20.1	—
	6	37,200	42,800	3.0	1.5	144	18.8	—
	8	33,200	40,000	2.0	1.2	138	18.3	—
Anneal 1750 F 2 Hr., Slow Cool	1	45,500	63,300	19.0	16.0	148	21.1	—
	2	42,900	60,300	14.5	13.8	143	20.7	—
	4	34,000	44,100	4.0	3.0	134	17.8	—
	6	34,500	41,200	3.0	1.8	131	17.0	—
	8	34,100	36,600	2.0	1.0	128	17.0	—
1550 F 1 Hr., Oil Quench, Draw 2 Hr. to Brinell as Shown	1	91,800	107,300	3.5	3.2	269	21.4	—
	2	87,000	101,900	3.0	3.0	269	21.4	—
	4	82,000	83,400	0.5	0.5	262	19.0	—
	6	63,000	66,800	1.0	0	214	17.3	—
	8	61,200	62,900	0.5	0	229	16.7	—

we have had no experience with its behavior in conjunction with dry wear, the very nature of the graphite formation leads us to assume that the resistance to heat checking is lower in nodular iron than in cast iron, and, consequently, that the resistance to dry wear will be lower. Some data have appeared in the literature which tend to substantiate this assumption.

Applications and Cost

It is only natural that our analysis of the uses to which this material can be put is influenced by the extensive application and outstanding success that non-flaky graphitic materials have had in our own manufacture. This has been especially so in the case of our 1.0 and 1.50% carbon cast graphitic steel, the latter of which is used in our current crankshafts. Some 20 million of these cranks have given excellent performance in service.

In an attempt, however, to approach the subject on a broader plane, we would like to break down the potential uses to which nodular iron might be applicable into four groups on the basis of engineering properties.

The first of these is that entire field where a non-flaky graphite in a selected matrix has proved so successful. From an engineering standpoint this would place nodular iron in direct competition with the various types of malleable irons as well as with our own graphitic steels. An extensive testing program to evaluate the suitability of nodular iron as a replacement for our present graphitic steel in the manufacture of crankshafts has been underway for about two years in the Ford Motor Co. The results to date are promising.

The second field where this material might find application is as a replacement for conventional cast iron where the strength, modulus, impact, etc. has proven inadequate or as a material competitive with the high strength and acicular irons.

Third, nodular iron might find application as a replacement for steel castings where the castability or machinability of the part in question might dictate its consideration. A noteworthy example of this is the work at Cooper-Bessemer cited by Eagan and James (*Iron Age,* Dec. 8 and 15, 1949) where nodular iron castings are indicated as comparing quite favorably with steel castings for component parts of engines and compressors.

Finally, there is some evidence to indicate that nodular iron can be hot worked in the neighborhood of 1750 F with good results. As our own experience in this field has been rather limited, we will cite some of the very interesting work that Rehder is carrying out in the Laboratory of the Department of Mines and Resources in Ottawa, Canada. Rehder has been successful in hot rolling 3-in. cast slabs in two heatings to 7/16-in. plate with a resultant tensile strength as rolled in the order of 140,000 psi. with 4% elongation.

The structure of hot worked material, as shown in Fig. 3, is similar to that of wrought iron, except that there is practically no pearlite in wrought iron whereas the matrix in as-rolled nodular iron is completely pearlitic. From these findings Rehder concludes that, since for the production of such material blast furnace iron could be treated at the furnace and the ingots rolled directly into plates or bars, the cost should be lower than for steel; this immediately suggests its use for concrete reinforcing bars, etc.

In order to critically evaluate the importance of nodular iron, it may be helpful to study Table III which shows a tabulation of physical properties representative of various cast ferrous alloys and some figures pertaining to their relative cost of manufacture.

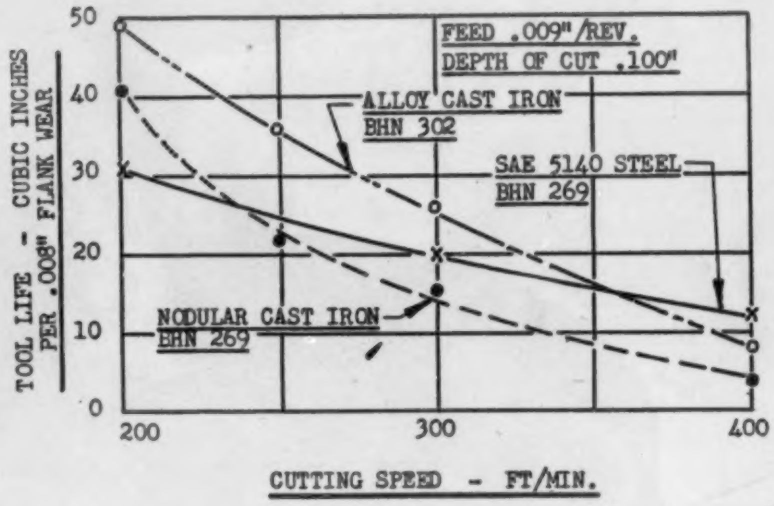
Since it has not been possible, in our work, to develop any exact data on cost, these figures have been arrived at by using basic costs of raw materials, cost of magnesium alloys and treatments as indicated by our experimental work, conversion costs for various types of melting units as listed by Gregg (*Foundry*, Feb. 1949), and standard assumption as to melting and heat treating practice.

It is evident that these figures can only serve as a guide in comparing the materials and conditions listed in the tables and must be modified according to the practice peculiar to each particular foundry.

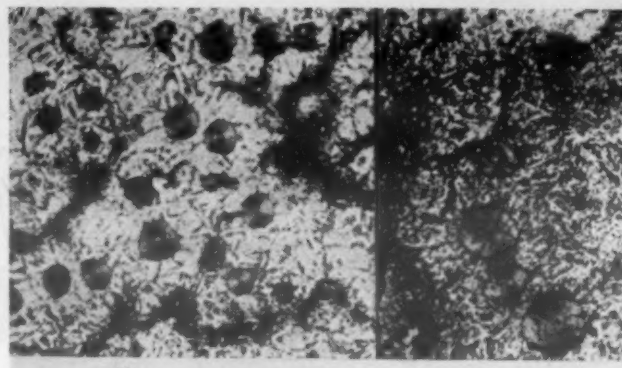
Assuming that the approach is valid and that the material, conversion and heat treat costs are representative, the following conclusions seem justified:

1. That there is no immediate economic advantage in replacing present malleable iron castings with nodular iron, but that its early application in the malleable field may be limited to section sizes larger than those possible at present.
2. That the competition with gray irons will be solely on the basis of improved engineering properties except in the case of alloy irons where an economic advantage is indicated.
3. That the use in the steel foundry industry will probably be limited to cases where improved castability and machinability will offset an increased cost of manufacture.

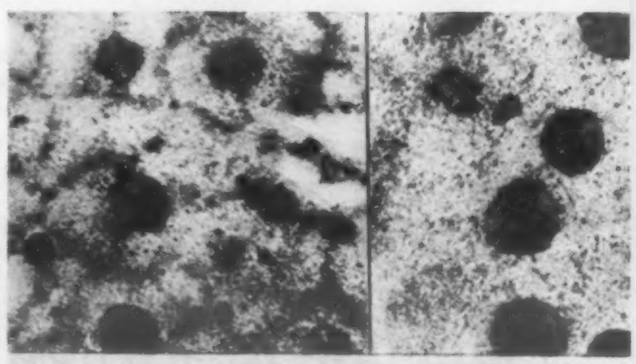
In summarizing the foregoing discussion, it can be said that nodular iron offers an engineering material which possesses properties never attained in flake graphite cast iron. The potential applications for this material seem to be many and varied, but it is entirely too early to predict all of its eventual uses. Currently, certain economic barriers exist, such as cost of treatment and the need for high-priced raw materials. Indications are, however, that research in this country and abroad will soon lead to developments which will permit nodular irons to assume a much more competitive role and thereby come into their full use.



Cutting speed vs. tool life for nodular iron compared to some other ferrous metals.



2" SECTION 8" SECTION



2" SECTION 8" SECTION

Effect of section size on microstructure of quenched and tempered nodular iron. Above, high ductility type; below, high strength type.

Acknowledgment

The authors express their appreciation to the Ford Motor Co. for permission to publish the data contained in this paper, and to the Vanadium Corp. of America for their excellent cooperation through their development of various alloys; in particular, the magnesium-copper-ferrosilicon alloys.

This article is based on a paper presented at the annual meeting of the Society of Automotive Engineers, Jan. 13, 1950.

Table III—Properties of Nodular Iron and Other Ferrous Metals

Property	Gray Iron SAE 111	Alloy Iron Ni, 0.80 Cr, 0.20 Mo, 1.00	Malleable SAE 35018	Pearlitic Malleable SAE 43010	Steel SAE 0030	Steel SAE 0105	Nodular Iron High Strength	Nodular Iron High Ductility (As Cast)	Nodular Iron High Ductility Annealed
Yield Point, Psi.	—	—	35,000	43,000	35,000	85,000	80,000	55,000	45,000
Tensile Strength, Psi.	30,000	70,000	53,000	60,000	65,000	105,000	100,000	80,000	65,000
Elongation, %	—	—	18	10	24	17	1.5	10	16
Reduction in Area, %	—	—	—	—	35	35	1.0	8	20
Brinell Hardness	190	286	130	170	130	217	255	190	160
Modulus of Elasticity	19×10^6	21×10^6	25×10^6	25×10^6	30×10^6	30×10^6	24×10^6	24×10^6	24×10^6
Impact Ft.-Lbs., 0.798-Dia. Bar	10	20	—	—	—	—	40	180	260
Type of Melting Unit	Cupola	Cupola	Cup. El.	Cup. El.	E. Fce.	E. Fce.	Cupola	Cupola	Cupola
Heat Treatment	None	None	Anneal	Anneal	Anneal	Quench & temper	None	None	Anneal
Casting Yield, %	80	75	52	50	50	50	70	70	70
Metal Cost per Ton Castings:									
Raw Material	$40.81	$70.73	$40.40	$40.95	$31.85	$46.84	$59.64	$63.86	$63.86
Conversion	6.75	7.20	14.60	15.18	31.83	31.83	7.71	8.65	8.65
Heat Treating	—	—	9.00	9.00	9.00	18.00	—	—	6.00
	$47.56	$77.93	$64.00	$65.13	$72.68	$96.67	$67.35	$72.51	$78.51

The pressing of metal powder parts is critical from the standpoint of design. Shown here are the essential elements of the pressing operation.

Designing Structural Parts for Powder Metallurgy

by H. R. CLAUSER, Managing Editor, Materials & Methods

Soundly engineered metal powder parts and their efficient production requires close cooperation between user and fabricator and a knowledge of the method's design limitations.

• THE SUCCESSFUL USE of powder metallurgy for producing structural parts depends to a large extent on proper design. Like other fabricating methods, it has design limitations which must be considered to produce a soundly engineered product and to facilitate efficient low cost production. This article will point out some of the main design considerations and will give two case histories to illustrate the advantages of designing specifically for powder metallurgy.

It is a common engineering axiom that a part should be designed always keeping in mind the method by which it is to be produced. Therefore, metal powder structural parts should be designed specifically for the process. However, since powder metallurgy is still relatively young compared to such methods as machining, casting, stamping and forging, the natural tendency is to base designs on older, conventional methods of production. This has in many instances prevented using powder metallurgy to best advantage.

In order to design specifically for powder metallurgy, there must be close cooperation between the metal powder parts user and the fabricator, particularly in the initial stages of planning and design. As in designing for any method of production, metal powder parts should be designed in close conjunction with the entire assembly. By giving the fabricator an

opportunity to review the design of the part in relation to the whole assembly before designs are frozen, changes in the assembly can often be effected which make possible a design which is better fitted to metal powder fabrication. And not infrequently does such a survey of the entire assembly reveal other parts which could be made by powder metallurgy with resultant simplification and reduction in costs.

Closely related to design is the tooling required to produce the part. Once it has been decided to make the part of metal powder, tool and part design should proceed together until a satisfactory part design and practical tools and dies have been devised. As is frequently the case, the initial design is not the most practical from the standpoint of tooling. By consultation between the designer and fabricator small design changes in the part can often be effected that will permit the use of simpler tools and also facilitate actual production.

When relatively simple parts, or parts of a type previously produced are being designed, the final production tools are usually made without first experimenting with temporary tools. However, where untried and complex parts are involved and where it is practical and economical to do so, temporary tools and sample parts are sometimes made to test the feasibility of using powder metallurgy before going into production. This permits tests to be made on the actual part. It also gives information on whether the tool design is practical and whether the proper powder composition is being used. However, it should be pointed out that development work such as this raises the over-all cost, whether it is done by the custom fabricator or by an in-plant department. Nevertheless, with types of parts on which there has been no or little previous experience, such a procedure may be necessary and can often prevent misapplication or scrapping of costly production tools.

Some Design Limitations

As is well known, production of metal powder parts involves two major operations—pressing and sintering. Pressing is most critical from the standpoint of design. The feasibility of making a part by powder metallurgy depends largely upon whether or not the dimensions, shape, detail and density can be obtained by pressing the powder in the die. Although space does not permit a detailed discussion of all design considerations, it might be well to mention the major limiting factors that must be kept in mind.

One of these is lack of lateral flow of metal powders before and during pressing. Therefore, the design must be such that the powder can be placed in the die in its relative final mold location. Another major limiting factor is that the pressing pressure is exerted only from top and bottom and not from the sides. This presents problems of getting uniform density throughout the piece. And the third limiting factor is the tools. Since the tools and dies are subject to enormous pressures, shapes that require a weak tool design must be avoided.

The above factors either alone or together account for a large share of the design limitations. Some of the most important of these are:

(1) In general, lengths of parts in the direction of pressing are limited to 2 and 3 in.

(2) Feather or knife edges, narrow and deep splines, and small thin projections should be avoided.

(3) True spherical sections are generally not practical unless there is a small land or flat of 0.010 to 0.020 in. on centerline.

(4) Holes not parallel to direction of pressing cannot be formed.

(5) Internal or external threads, reentrant angles and undercuts cannot be molded.

(6) The limiting ratio of axial to radial dimensions is generally put at 3 to 1, but it sometimes goes as high as 7 to 1.

(7) Variations in thickness in direction of pressing are usually limited to three, although as many as five have been successfully molded with special set-ups.

(8) Sharp corners and edges should be avoided by use of bevels, fillets and chamfers.

Metal Powder Padlock

The pin tumbler padlock, consisting of a number of metal powder parts made by American Sintered Alloys, Inc. for Reese Padlock Co., is an excellent example of how powder metallurgy is used to best advantage when the assembly is specifically designed for this method of production.

Fig. 1—Pin tumbler padlock and the four parts made by powder metallurgy. The lock body has been sectioned to show design detail (bottom). Also shown are outer cylinder (left), inner cylinder (right) and bolt (center).

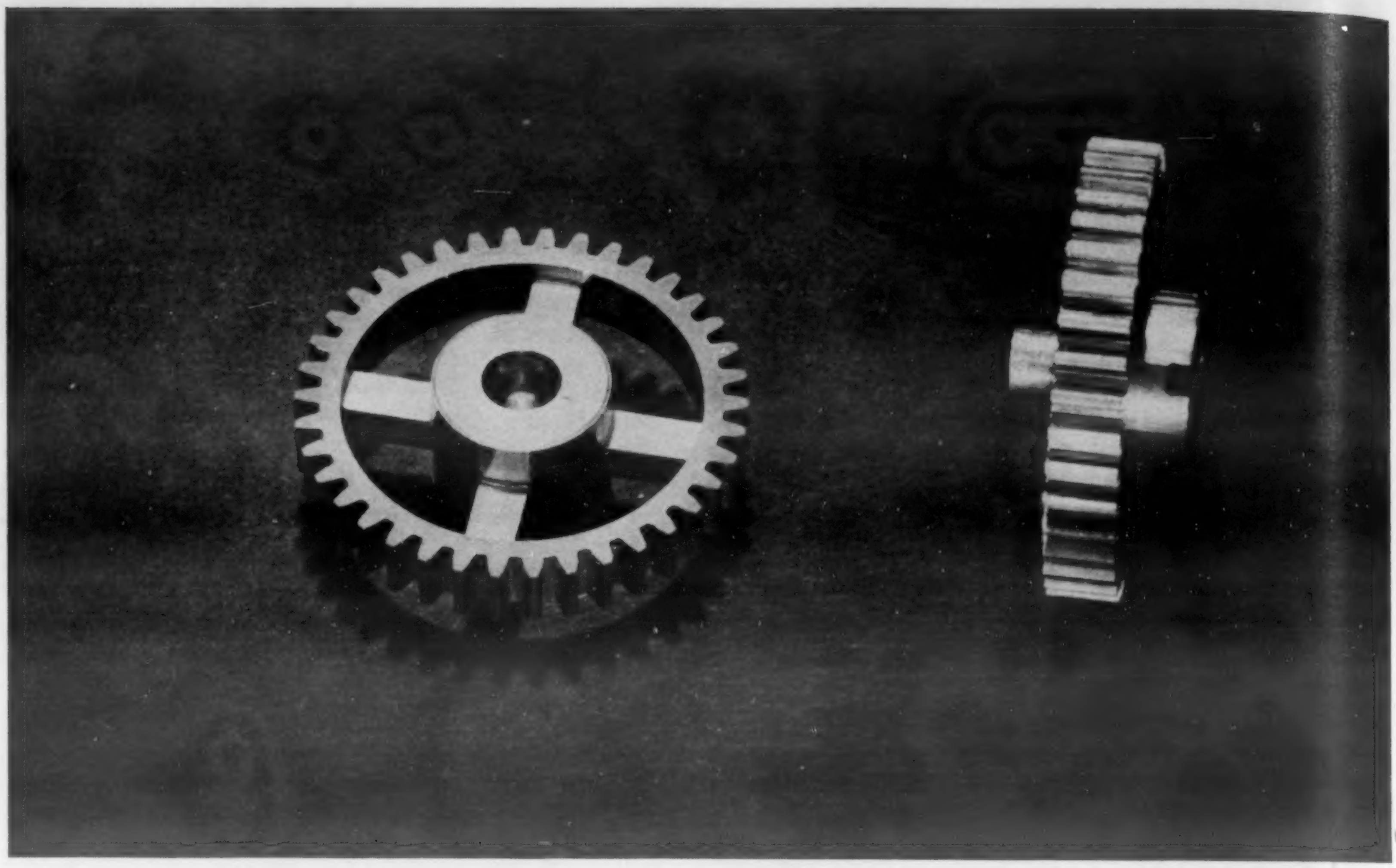


Fig. 2—Two metal powder gears showing the design first used.

Lock cylinders, alone, had previously been made from brass powders; their successful performance and savings in production costs prompted consideration of powder metallurgy for other lock components. As a result Reese Padlock Co. developed a design with powder metallurgy in mind as one of the possible methods of production. They submitted the original drawings to the fabricator, who suggested changes that should be made to take full advantage of powder metallurgy, and these were incorporated in the redesign.

The final design called for all major components of the lock, except the hardened steel shackle, pins and springs to be produced by powder metallurgy. The brass powder components are shown in Fig. 1, and include the lock body, inner and outer cylinders, and the bolt. The inner cylinder fits into the outer cylinder and this assembly push fits into the opening provided in the lock body. The bolt rests at the bottom of the body opening and slides in a channel provided there.

The components are made of an 80-20 leaded brass powder using conventional powder metallurgy production methods. The parts are pressed at between 30 and 50 tons psi. and have a sintered density of between 7.9 and 8.2 gm. per cc. Since the material is somewhat softer than cast metal, a little more care must be exercised in production handling. The finish on the parts is excellent and the lock body is easily finished to a dull hardware finish with a 180 grit belt to remove any marks or knicks caused in handling.

An important factor in deciding on powder metallurgy was the low initial investment compared to making the lock components of machined extrusions. The entire tooling program, including jigs, milling machine fixtures, gages, assembling fixtures as well as powder metallurgy tools, ran under $10,000, which is considerably below that which would be required if the lock had been made by other methods.

The lock body is approximately 1½ in. long by 1⅜ in. high and is ¾ in. thick across the center. The sectioned body in Fig. 1 shows the unique design made possible by powder metallurgy. It permits the use of shoulders near the bottom of the hole to act as a stop for the cylinder assembly, and also permits inclusion of the channel or track in which the bolt slides. These internal design features are gained without additional operations subsequent to pressing and sintering. This relatively simple lock body design is not possible if any other production method were to be used. For example, the end of the cylinder hole where the bolt slides could not be machined to the required shape at a reasonable cost.

A further advantage of the lock body design is that it made possible redesign of the bolt so that it too could be produced by powder metallurgy. On the first pressings it was found that the top surface of the bolt "brinelled" by impact from shackle upon repeated closing of lock. This condition was eliminated by a change in powder composition to give increased hardness.

The original design of the lock body specified that the shackle holes should be molded in. The holes are approximately ¼ in. in dia. and the deeper of the two is about 1 in. long. For most practical tooling and production, the fabricator recommended that these holes not exceed ⅜ in. in depth. Therefore, the design was changed so that now the holes are spotted and later drilled in a subsequent operation.

The design of the inner and outer cylinders serves to illustrate some of the things that can and cannot be done by powder metallurgy. Both the lead to the keyway and the keyway in the inner cylinder show the intri-

cate shapes that can be successfully obtained without the need of subsequent machining. This is possible largely because the keyway runs parallel to the direction of pressing.

On the other hand, the pin holes in both cylinders cannot be molded, but must be drilled, because they are at right angles to the direction of pressing. Also, the groove at the one end of the inner cylinder represents an undercut that cannot be formed by pressing. However, most other methods of production would also require these machining operations.

The tolerances between the two cylinders and between the outer cylinder and lock body are quite critical. The clearance between the outer and inner cylinder must be about 0.004 in. for proper operation, and the outer cylinder must have a push fit into the body.

Metal Powder Gears

The case of two gears produced by Moulded Metals Co., Inc., for use in a metering device provides another good example of how to design specifically for powder metallurgy. These two parts are shown in Fig. 2. One of the gears functions as an intermittent drive gear and in operation starts and stops instantly in repetitive cycles. Therefore, it must be wear resistant and strong enough to withstand a mild shock loading. The other is a clutch spindle gear and has much the same service requirements as the first. Both gears are subjected to metal-to-metal contact.

The two gears are similar in general design. They are approximately 2⅞ in. in dia., and have 38 teeth. The drive gear has a keyway in the hub whose position in relation to the gear teeth is critical and must be held to within less than 1 deg. Other critical tolerances run between ±0.002 and 0.003 in.

The gears were formerly fabricated by brazing the hub to a 1020 steel forging. This method of production required expensive machining and hobbing operations in addition to the brazing step. By producing them by powder metallurgy methods it was found that the cost per gear could be cut 60%. This cost reduction has been realized in spite of the fact that to make the part of metal powder successfully requires a repressing and coining operation and two sinterings.

The sequence of operations to produce the gears is as follows: (1) press at 40 ton psi. in a hydraulic press; (2) sinter at 2100 F for 15 min.; (3) repress almost to size at same pressure; (4) sinter at 2100 F for 40 min.; (5) coin to final size. The final sizing actually burnishes the gear teeth so that no other finishing operations are needed. Hardening of the teeth is not required. Tests on hardened gears showed no increase over the as-sintered gears in wear resistance.

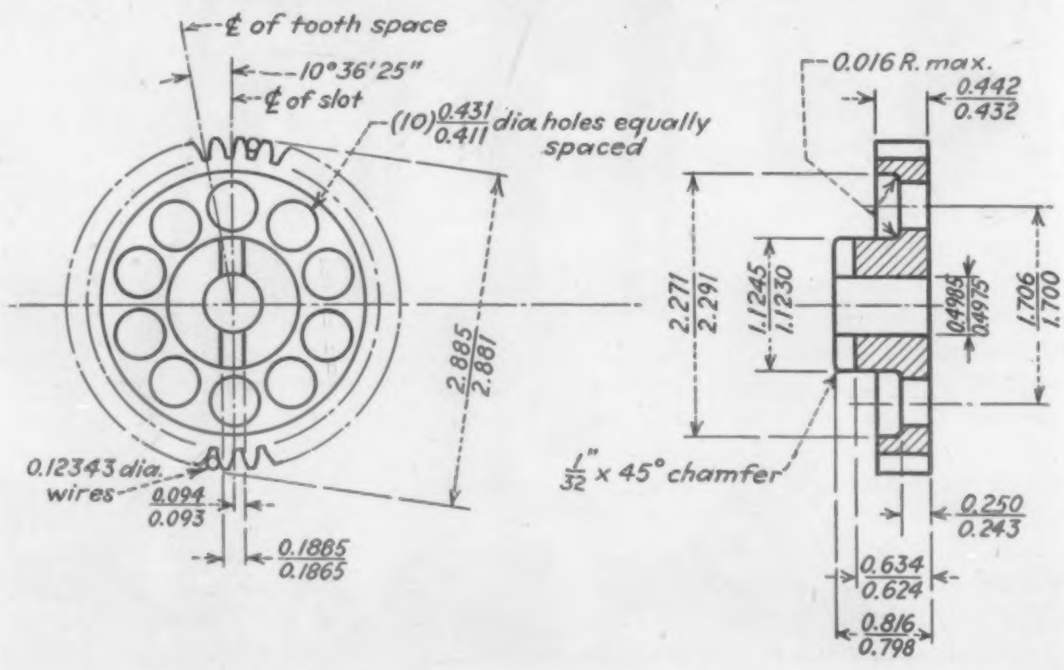
The gears at present are being made of iron powder with 1% graphite, which gives strengths of between 40,000 and 45,000 psi. It is planned to change to a 95 iron-5% copper powder which will increase the strength to around 50,000 to 55,000 psi. Before the metal powder gears were finally decided upon, several simulated service, long life tests were conducted. The drive gear, for example, was subjected to 7,000,000 operations, at the end of which it was deliberately jammed while in cycle. No damage to the gear resulted, although the mechanism of which it is a part failed. Also the test produced no appreciable wear on the gear teeth.

The original design of these gears for powder metallurgy differed little from the forged and brazed assembly. The web joining the hub and gear ring, for example, was solid. Since this large surface area would have required an exceptionally large press, the gear was redesigned with spokes replacing the solid web, thereby cutting down considerably on the molding area.

Although this design proved satisfactory, and several thousand gears were produced, it was found that with certain additional design changes production could be further facilitated and the cost per piece reduced another 15%. Fig 3 shows the drawing of the redesigned drive gear. It will be noted that the spokes have been replaced by a web containing ten holes. Also, the small pin projection present on the hub in the other design is not molded along with the gear; a steel pin insert is now pressed into the hub in a subsequent operation.

The advantages gained by this redesign are many: (1) Tool design is simplified, thereby reducing tooling costs. The die set for the first design consisted of 21 parts as compared to 16 in the new design. Whereas the spoke design required four separate carefully ground die pieces, the new web design requires only one with core pins to form the holes. (2) Elimination of spokes permits a smoother hub bearing surface to be formed in pressing, thereby eliminating a machining operation. (3) Pressing of the metal powder compact is simplified by elimination of the four spoke die pieces already mentioned. Also, the first design had five thickness changes in the direction of pressing. By eliminating the hub pin these changes were reduced to four, which proved a considerable help in pressing. (4) Final density has been increased. With the first design densities of 85 to 90% were obtained. With the new design 88 to 90% densities are assured. (5) Slight separations occasionally appeared in the spokes near the gear ring in the first design. Although these had caused no failures, it was felt desirable to eliminate them if possible, and this was accomplished with the new design.

Fig. 3—Drawing of the redesigned drive gear. The clutch spindle gear was similarly redesigned to take best advantage of metal powder fabrication.



Joining Large Sections of Low Alloy Steels by Gas Pressure Welding

by A. I. NUSSBAUM, Mond Nickel Fellow, London, England

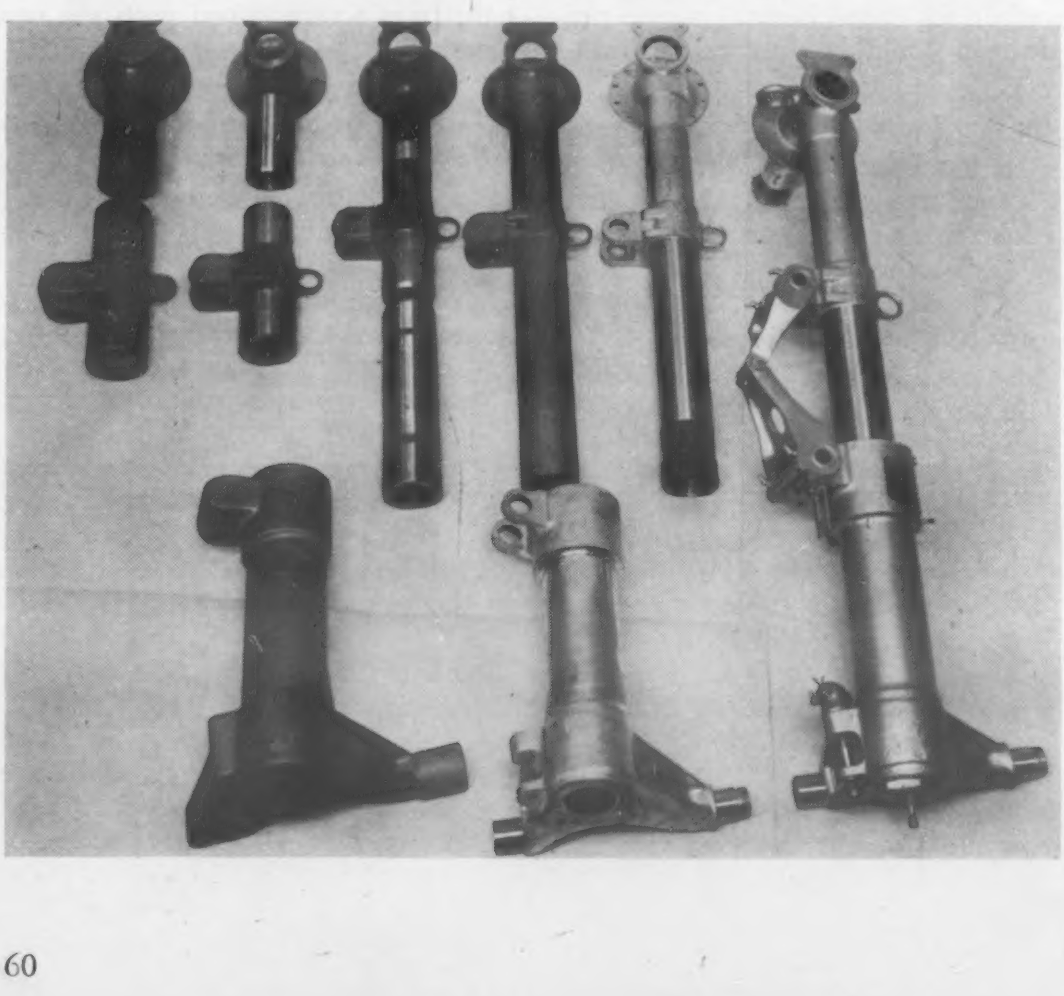
Minimum weight construction, less machining, and lower welding costs have resulted by adopting this method of fabricating aircraft landing gear.

• WITH FIGHTER-BOMBERS landing at speeds up to 150 mph., the importance of well-constructed landing gear can hardly be over-rated. It is significant, therefore, that the relatively new gas pressure welding process is playing an important part in the production of low alloy steel landing gear at Menasco Manufacturing Co., Burbank, Calif. This company turns out about 30% of the landing gear for United States military aircraft, and its fabricating techniques represent a highly advanced application of the pressure welding process.

The basic pressure welding process has been patented by Linde Air Products Co. In 1943, Menasco became interested in its application to the fabrication of pipe lengths for oil well drilling, a development which led eventually to the present-day welding of landing gear components. The company is now a licensee of the Linde patent and has termed its own particular application the "Uniweld Process."

Fabrication of landing gear units by means of oxyacetylene pressure welding allows minimum weight construction and eases the machining problem; on the other hand, it requires extremely reliable welds having maximum physical properties. The first part of this two-part article will discuss in some detail the principal features of the Uniweld Process, including surface preparation and welding equipment and procedure. A second article, to be published in a subsequent issue of MATERIALS & METHODS, will cover the unique inspection and testing procedures employed by the company to ensure the high quality welds so essential in this application.

Fig. 1—Step-by-step fabrication of a Uniwelded aircraft landing gear. (All photographs courtesy of Menasco Manufacturing Co.)



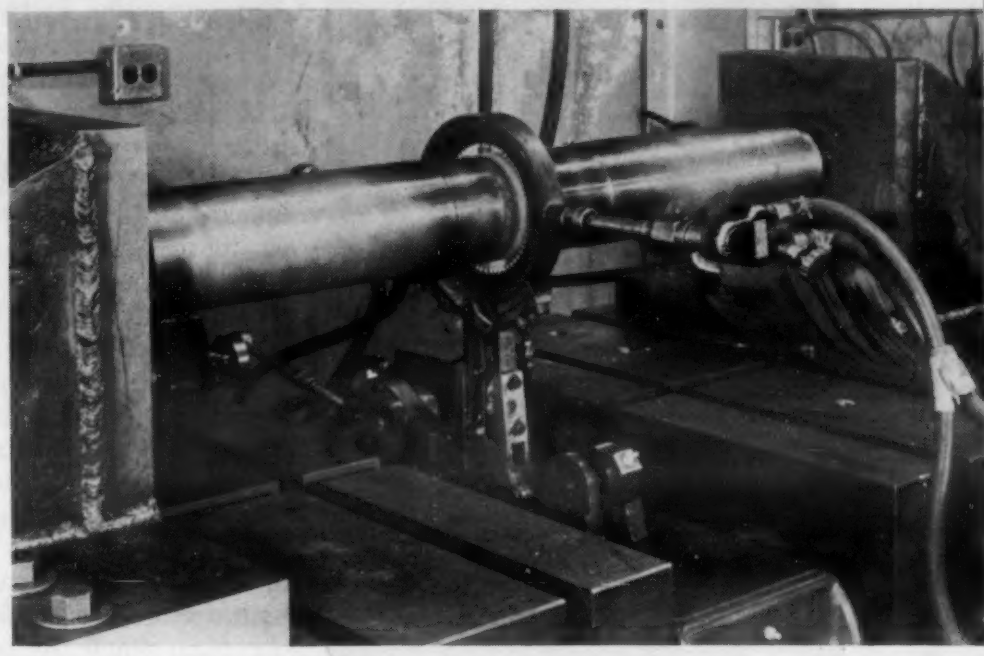
Principle and Application

Uniwelding is accomplished by butting together under pressure two machined faces of the parts to be welded, at the same time heating the area of the weld plane until sufficient upsetting takes place. The process depends upon heat, pressure and intimate contact of the surfaces to be welded, which, in turn, requires exclusion of air or any material that might cause physical or chemical discontinuity between the butting weld faces. Bonding is provided by cohesion of metal at the weld plane due to the atomic attraction forces resulting from intimate contact of the weld surfaces. Practically, this close contact is effected by the upsetting operation, which also serves to break down inhibiting films on the weld faces and cause recrystallization across the weld plane. (Further re-orientation of grains occurs during subsequent heat treatment.)

In general, this company is applying the gas pressure welding procedure to chromium-molybdenum and nickel-chromium-molybdenum low al-

Fig. 3—Typical gas pressure weld before machining.

Fig. 2—Close-up view shows heating head designed for welding tubing.



loy steels (SAE Series 4100, 4300, 8600 and 8700) within limits of 0.25 to 0.45% carbon, and to components having tubular cross-sections of 1- to 20-in. O.D. and a minimum wall thickness of 0.125 in. All Uniweld joints are heat treated to regain a tensile strength of 180,000 to 200,000 psi.; weldments having a joint strength in bending of at least 100% of parent metal strength can be produced with a high degree of consistency.

It is because of this consistent high joint quality that gas pressure welding has been found particularly well suited for landing gears. Economies are achieved because parts difficult or impractical to forge and machine in one piece can be fabricated from simple sub-assemblies into one unit possessing physical properties equal to those of an equivalent part made in one piece. Uniwelding also lends itself to economies in mass production; use of holding fixtures for rapid alignment of parts permits a high rate of production and a reduction in costs.

Other fabricators, using the flash butt welding process, have been qualified by the U. S. Army to weld landing gear components involving areas up to 18 sq. in.; the Uniweld Process, however, has been approved for areas up to 60 sq. in. For today's largest airplanes the process furnishes the only alternative to the use of unwieldy components difficult—if not impossible—to forge and machine. In the small diameter field, flash butt welding is generally more economical; although areas as small as 1 sq. in. can be Uniwelded successfully, the process is applied most advantageously to assemblies having areas in excess of about 6 sq. in.

Surface Finish

The necessity for intimate contact of the weld faces makes close control of surface finish particularly important. The finish prior to welding of the butting faces is required to conform to the following specifications:

1. Surface roughness shall not exceed 50 micro-inches root mean square on tubes with wall thickness of 5/32 in. or less.
2. Surface roughness shall not exceed 100 micro-inches root mean square on tubes with wall thickness in excess of 5/32 in.
3. Weld surface shall be normal to the center line of the part being welded.
   a. *Concavity*—light showing beneath a straight edge held directly across the entire weld face indicates excessive concavity and will be cause for rejection.
   b. *Convexity*—slight convexity to the extent of 0.002 in. per in. of wall thickness may be permitted.
4. Tool marks running concentric with the circumference and others within normal operating practice may be permitted, providing surface finish requirements are not exceeded.
5. Visible nicks, scratches, oxidation or other similar irregularities are not acceptable.

Commercially feasible machined finishes on the faces of parts to be pressure welded are coarse when considered in the light of the percentage of total surface area in true contact at welding pressures. These welding pressures are in the range of 3000 to 10,000 psi., based on nominal cross-sectional area. True contact at these pressures, however, consists merely of the touching of high points while the majority of the surface is in no contact whatsoever. The non-contacting surface is exposed to entrapped air. The most obvious means whereby increased contact is established during welding is plastic deformation. Some plastic deformation occurs even while the parts are cold, since, instead of the 3000 to 10,000 psi. value, the pressure at the contacting points is actually well over the elastic limit of the material. This high local pressure is due to the sharing of the compressive load by only a fraction of the nominal cross-sectional area. As heating begins and the temperature of the parts rises, the compressive strength of the material decreases, permitting progressively more deformation up to the completion of the weld. This continuously increasing inter-face formation makes possible additional atomic bonding.

Welding Equipment

The equipment required for Uniwelding is essentially a press of appropriate capacity equipped with fixtures for holding in alignment the parts to be welded, an oxyacetylene heating head and a device to measure and control the amount of "gather" (shortening of the parts due to upsetting). A movable carriage is axially loaded by two hydraulic pistons moving in a plane through its centerline; such axial loading minimizes misalignment or angularity of the components. In addition to a 16-in.

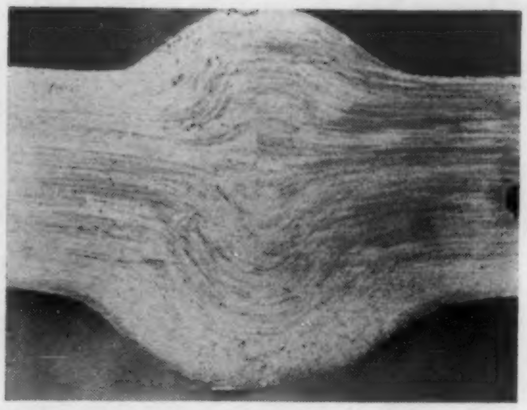


Fig. 4—Macrograph of tube wall cross-section reveals details of pressure weld.

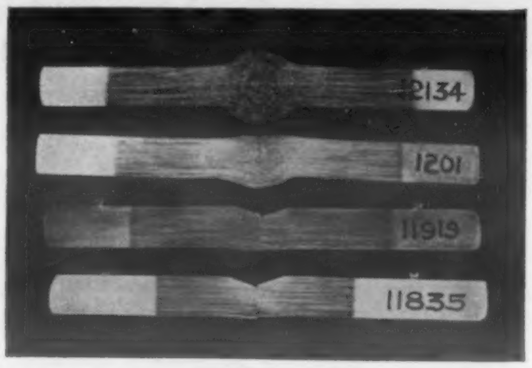


Fig. 5—From bottom to top, these sections were Uniwelded with increasing amount of gather.

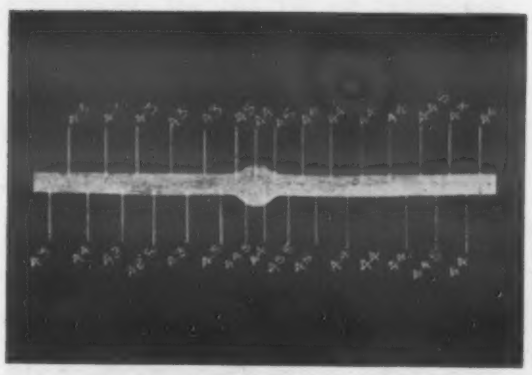


Fig. 6—Hardness survey of Uniwelded joint and heat affected zone after furnace normalizing.

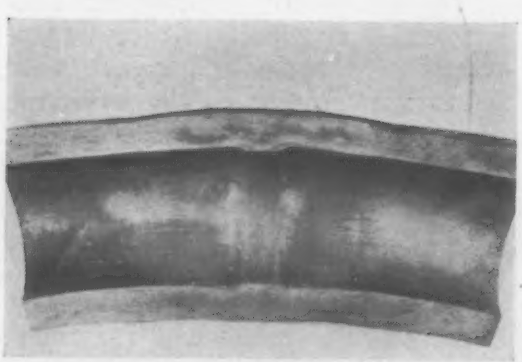


Fig. 7—Internal upsets easily machined to remove small cracks or fissures.

machine, several similar machines of different sizes make it possible for the company to cover a wide field of gas pressure welding, ranging from 100-sq.-in. down to 1-sq.-in. cross sectional area.

The principal requirement of a machine's heating head is to produce a high temperature throughout the weld interface at a rate suited to the particular section. The linear heat gradient, both axial and radial, must also be considered so that differential thermal expansion does not open up the weld faces. By means of cam or eccentric action, the heating head usually is made to oscillate laterally and/or angularly so as to distribute the flame from each orifice over an appropriate area; this not only transfers heat efficiently but also prevents overheating of the metal beneath the flame tips. The water- and gas-cooled heating head shown in Fig. 2 has forty 0.033-in. dia. orifices, equally spaced and drilled radially in the inner ring surface, and is designed specifically for the welding of tubing. All Uniwelding machines apply heat to the external surface of the tube; to date, no internal heating head has ever been employed.

The five variable factors involved in making a pressure weld are pressure, heat input, gather, temperature and time. In practice, only the first three are controlled. Temperature is not easy to measure with precision. It depends upon heat input, and the amount of gather under pressure shows whether a suitable subfusion temperature has been obtained. Similarly, time is a function of heat input, so that its control is also indirect. The factors actually controlled in the present Uniwelding equipment are listed below. All may be varied to suit individual joint designs, and they can be held within the tolerances shown.

Variable	*Tolerance*
1. Acetylene gas pressure and flow	±7%
2. Oxygen gas pressure and flow	±2%
3. Hydraulic pressure determining welding force	±5%
4. Gather control	By limit switch

The gas and hydraulic pressure controls and gages are mounted on the machine base. The extent of upsetting can be controlled effectively by means of a limit switch fitted with a dial indicator gage. Once the required amount of gather has been achieved, this limit switch turns off the hydraulic pressure and, simultaneously, the fuel gas supply to the heating head.

Welding Procedure

In practice, parts are machined with a good finish on the weld faces and located solidly in the welding machine by fixtures providing accurate alignment. The butting faces are cleansed with a grease solvent, and alignment is checked by means of a tissue paper impression test. All controls are set, and the upsetting pressure is applied before the heating head is lit. The heat, being concentrated at the weld plane, limits upsetting to a relatively small volume at the weld plane. Finally, the gather control mechanism shuts off the heat and pressure. Typical Uniwelds involve temperatures of 2400 to 2500 F, and welding time ranges from a few seconds to several minutes, depending on the wall thickness of the weld. Once the welding cycle is completed, the part can be removed from the machine immediately and a new weld started.

A typical gas pressure weld is illustrated in Fig. 3. The size of internal and external upsets, the alignment of the specimens, the contour of the flow lines, and the plane of juncture can be seen in the macrograph reproduced in Fig. 4. The inside diameter upsets generally are larger than the outside diameter ones. Occasionally, small fissures (a fissure is defined as any unwelded portion of the internal or external upset) or cracks occur on the internal upsets; the larger size of these upsets makes it an easy matter to machine off such flaws. No fissures are ever located on the outside upsets of approved welds. Due to the close proximity of the flame, however, a small amount—not usually over 0.040 in.—of metal is "burned" and it is, therefore, desirable to remove part of the external upset as well.

The four macrographs reproduced in Fig. 5 represents sections Uniwelded with increasing amounts of gather and indicate how the shape of upset is affected by the amount of gather.

As the rate of cooling subsequent to pressure welding is low, a small spread of hardness occurs. Flame normalizing will reduce this spread considerably, and furnace normalizing of the entire component will completely obliterate the heat-affected zone, producing a flat hardness traverse as indicated by the Rockwell "C" scale numbers in Fig. 6.

Low-Carbon Stainless Steels Make Possible Savings in Welded Fabrication

By eliminating the need for expensive stabilizing elements and post-welding anneals, these relatively new materials reduce cost of fabricating corrosion resistant alloys in wide range of applications.

by **JOHN B. CAMPBELL,** Associate Editor, Materials & Methods

• THE PROBLEM OF intergranular corrosion in austenitic stainless steels has often forced the fabricator of large stainless equipment to choose between two expensive alternatives. To obtain long service life he could (1) anneal after welding to redissolve the precipitated carbide which makes the steel susceptible to intergranular corrosion, or (2) use a stainless steel containing expensive, and sometimes scarce, carbide-stabilizing elements. For extremely large components only the second course of action was feasible.

In recent years, however, improved steel manufacturing techniques have made possible economic production of austenitic stainless steels having maximum carbon contents of 0.03%, instead of the customary 0.08 to 0.10%. Although the exact mechanism of intergranular corrosion is not known, it has been found that lowering the carbon level reduces considerably the tendency toward undesirable carbide precipitation. As a result, many of the difficulties encountered in welded stainless fabrication seem to have been eliminated. In this article, attention will be given to the mechanical properties and corrosion resistance offered by these low-carbon stainless steels, and to the applications for which they appear particularly suitable.

Low-carbon stainless steels have been commercially available since 1945 when first produced by Armco Steel Corp.; however, usage of these new steels was not actively promoted until 1947. The Armco steels have been commercially designated as Extra Low Carbon grades and are currently available in Types 304 ELC, 316 ELC and 317 ELC. Late in 1949, Carnegie-Illinois Steel Corp. also announced commercial production of low-carbon grades of Types 304 and 316, with other types available for special applications. In each case, actual production was preceded by extensive research along two lines: improving manufacturing techniques; and determining whether the advantages offered by the low-carbon materials were sufficient to warrant the additional time and care required in melting.

In general, the results of these investigations have proved low-carbon stainless steels to be satisfactory substitutes for titanium- and columbium-stabilized grades for applications, such as welding, which involve short heating times. Thus, results of corrosion tests on welded specimens indicate that low-carbon stainless steel and columbium-stabilized steel have equal corrosion resistance in the as-welded condition. Furthermore, the corrosion resistance of a welded low-carbon stainless steel appears to equal that of its corresponding regular-carbon grade in the welded and annealed condition. However, although a carbon content not exceeding 0.03% largely prevents harmful carbide precipitation in the short heating periods occurring during welding, it will not insure protection at welds and in the base metal if subsequent service temperatures are within the sensitization range. Consequently, these steels should be specified only for welded equipment to operate at tem-

Welded structures of low-carbon stainless steel give good service in textile plants where many highly corrosive dye solutions are used. (Courtesy Armco Steel Corp.)

This 20-ft. dia. dish is part of a 50-ft. acid accumulator tank for a sulfite process paper mill. It will be lined throughout with low-carbon 316 stainless steel. (Courtesy A. O. Smith Corp.)

peratures below 800 F.

As would be expected, reduction in carbon content results in some sacrifice of strength. Nevertheless, the low-carbon materials have only slightly lower tensile strength, yield strength and hardness than the regular-carbon grades, and they are about equal in ductility.

Applications

Before low-carbon stainless steels were developed, it was often necessary to anneal stainless weldments or use the more expensive "stabilized" grades to prevent corrosive attack at the weld area. Removal of the necessity for stainless steel stabilized by additions of columbium or titanium not only results in economies for the fabricator but also frees him, especially in the case of columbium, from dependence upon the often critical supply of these stabilizing elements. Elimination of the necessity for annealing welds has permitted fabrication of large assemblies on the job and, in many cases, greatly simplified the problem of field repairs on stainless steel equipment.

In the three years that have passed since their introduction, the low-carbon stainless steels have found fairly wide application in the chemical, paper and pulp, petroleum and textile industries. Demand has been greatest for the molybdenum types, the low-carbon equivalents of Types 316 and 317, which have greater overall corrosion resistance than the 18:8 types. Several current applications of the low-carbon stainless steels are illustrated in the accompanying photographs.

Among the first applications for the low-carbon grade of 316 were chemical extraction tanks and sulfite digesters used in paper mills. Because of the size of such equipment, the reduction in initial cost achieved by using this steel instead of a "stabilized" grade amounted to several thousand dollars. Another early application was in a sulfur and steam recovery system in a paper mill. Installed in late 1947, the 6-ft.-dia. ducts, fittings and valves which required extensive welding are reported to be giving satisfactory service despite exposure to sulfurous acid, sulfur dioxide and steam.

Other applications in which this material is being used include: phosphoric acid tanks; steel mill pickling tanks holding nitric and nitric-hydrofluoric acids; boric acid tanks; chemical polishing tanks; bubble caps and risers in distillation units; piping and fittings in chemical, textile and paper plants; waste disposal units; and pressure vessels. Among many potential uses which might be listed are shipping containers and drying units in chemical plants.

The low-carbon grade of 304 is used for similar applications where the extremely high corrosion resistance offered by the molybdenum types is not required. Some specific uses include: welded tubing; smoke stacks and duct work in chemical plants; drawn shapes for welded assemblies; hoods and ducts for corrosive atmospheres in paper and textile plants; and annealing covers for hydrogen annealing of silicon steels. In this latter application the low carbon content is useful in that contamination of the heat treating atmosphere is avoided; if higher carbon steels were used the unit would have to be run until the excess carbon content had been reduced by the atmosphere.

Mechanical Properties

In the more detailed discussion of properties which follows, low-carbon (0.03% maximum carbon) stainless steels will be designated as LC-304, LC-316, etc., for purposes of clarity and brevity. Thus, LC-304 is identical in chemical composition with Type 304, except that its upper carbon limit is 0.03% instead of 0.08%.

Generally, the mechanical proper-

Table 1—Notched Bar Impact Strength of Arc-Welded ½-In. Plate

Impact Strength, Ft.-Lb. (Charpy Notch Location)	Temperature, F	304 (Electrode 308) As-Welded	LC-304 (Electrode LC-308) As-Welded	LC-304 (Electrode LC-308) Welded, Stress Relieved 2 Hr. at 1600 F, Air Cooled	316 (Electrode 316) As-Welded	LC-316 (Electrode LC-316) As-Welded	LC-316 (Electrode LC-316) Welded, Stress Relieved 2 Hr. at 1600 F, Air Cooled
Notched in Unaffected Plate Metal	75	73	76	75	57	54	55
	-105	—	90	79	—	59	58
	-320	—	71	70	—	51	44
Notched in Heat Affected Zone of Plate Metal	75	—	70	58	—	45	56
	-105	—	76	52	—	45	58
	-320	—	65	38	—	38	44
Notched in Center of Weld Metal Deposit	75	35	35	29	36	31	26
	-105	25	26	26	28	31	20
	-320	21	23	18	34	23	—

Adapted from data furnished by Armco Steel Corp.

ties of the low-carbon stainless steels do not differ radically from those of the corresponding higher carbon types. The average tensile properties exhibited by sheets of LC-304 and LC-316 are compared with those of 304 and 316 in Figs. 1 and 2. Thus, LC-304 is softer than its higher carbon prototype; its average tensile strength is 8000 psi. lower, average yield strength 3000 psi. lower, and average elongation about the same. And LC-316 is softer than 316; its average tensile strength is 5000 psi. lower, average yield strength 10,000 psi. lower, and average elongation 6% higher. It is evident that the low-carbon stainless steels are only slightly lower in tensile strength, yield strength and hardness than materials of regular carbon content, and that ductility of the two materials is about equal.

In tensile and bend tests on ½-in. thick plate, welded specimens of LC-304 and LC-316 have been shown to conform with the strength and ductility requirements of the ASME Code for Unfired Pressure Vessels.

Data on the impact strength of manual arc-welded joints in ½-in. thick plate of LC-304 and LC-316 are presented in Table 1. These materials, joined by electrodes of similar low-carbon stainless composition, were tested at room temperature and two subzero temperatures. The ASME Code requires a minimum impact strength of 15-ft.-lb. for materials employed in service at subzero temperatures. Results shown in the table appear to be typical of the austenitic stainless steels.

Impact tests, using the Charpy keyhole notch, have also been carried out at these same temperatures on wrought low-carbon stainless steels. Three different prior heat treatments were used: (1) ½ hr. at 1950 F, (2) 100 hr. at 1600 F, and (3) 2 hr. at 1200 F. In general, it can be said that the impact properties of LC-304 are relatively insensitive to both test temperature and prior heat treatment. The impact strength of

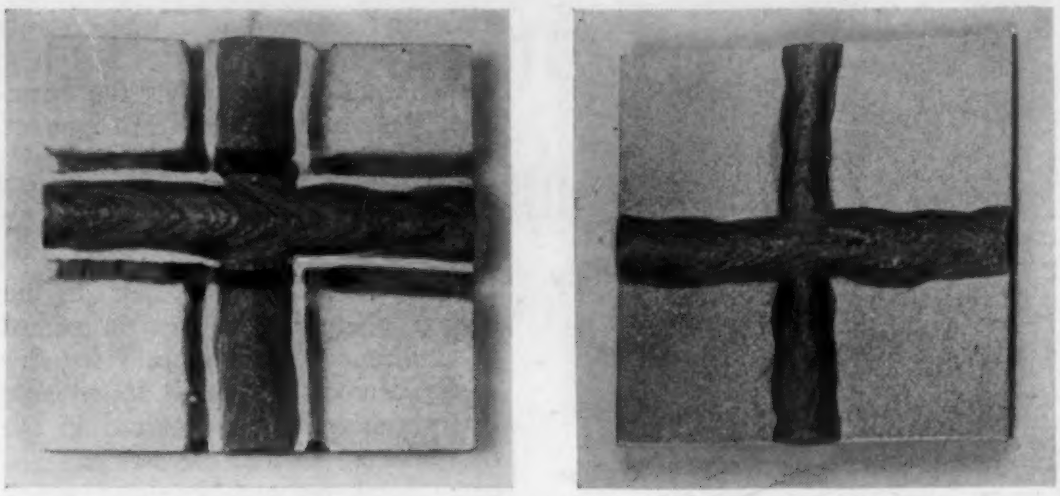


Fig. 3—Metal-arc welded ⅛-in. sheet after exposure to nitric-hydrofluoric acid. Type 304 (at left) shows severe intergranular attack; LC-304 (right) shows no localized attack. (Courtesy Armco Steel Corp.)

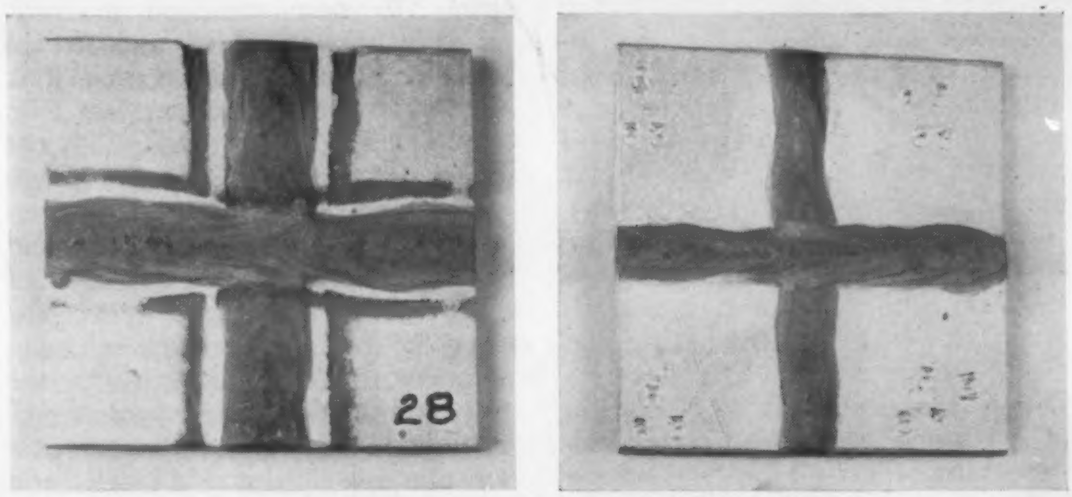
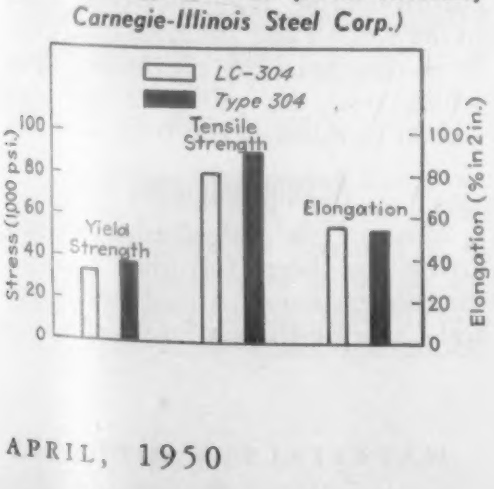


Fig. 4—Nitric-hydrofluoric acid produced marked intergranular corrosion of Type 316 (left) but no localized attack on LC-316. (Courtesy Armco Steel Corp.)

Fig. 1—Tensile properties of regular- and low-carbon Type 304 compared. (Courtesy Carnegie-Illinois Steel Corp.)

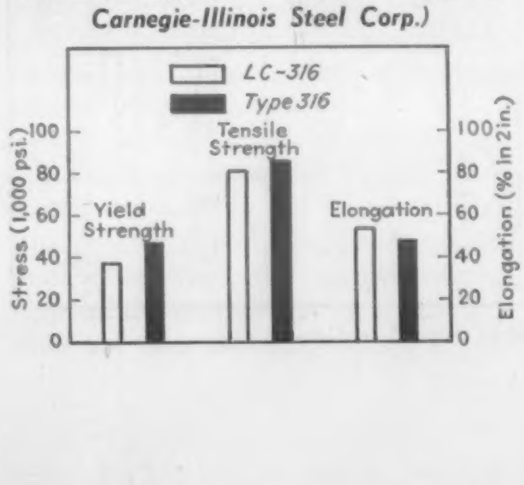


LC-316 decreases after the steel has been heated 100 hr. at 1600 F and, after this heat treatment, impact strength also appears to be sensitive to the test temperature. Impact strength of LC-347 is relatively insensitive to test temperature, with only a slight lowering of impact values noticeable after the 1600 F treatment. Columbium-stabilized LC-316, on the other hand, appears to react similarly to LC-316, a marked decrease in impact resistance occurring after the 1600 F treatment.

The influence of elevated temperatures on the tensile properties of annealed, wrought low-carbon stainless steels is given in Table 2. The data show that although the decrease in strength of LC-304 at elevated temperatures corresponds closely to that of its prototype, 304, the relative drop-off is much more rapid for LC-316 than for regular-carbon 316.

Tests at temperatures ranging from 1100 to 1500 F show that the stress required for LC-304 to creep 1% in 10,000 hr. falls on the low side of the band representative of 304. A comparison of the regular- and low-carbon grades of 316 shows again that the stress needed to cause LC-316 to creep 1% in 10,000 hr. is somewhat lower than the range of values representative of the higher carbon 316. It should be noted that, although short-time tensile data up to 1000 F and creep data up to 1500 F are available, low-carbon stainless steel weldments are recommended only for service at temperatures below 800 F.

Fig. 2—Tensile properties of regular- and low-carbon Type 316 compared. (Courtesy Carnegie-Illinois Steel Corp.)



Corrosion Resistance

In one series of accelerated corrosion tests, metal-arc-welded butt-type joints in ⅛-in. sheet were exposed

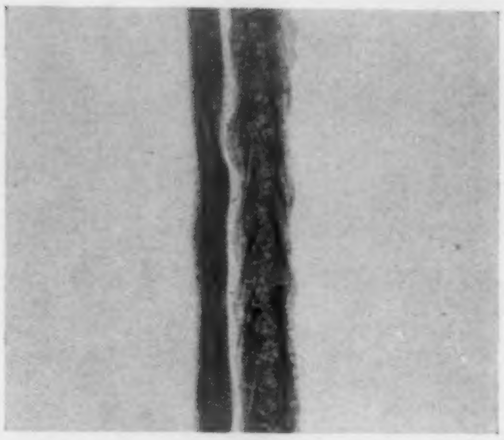


Fig. 5—Composite specimen of ⅛-in. sheet with Type 304 at left and LC-304 at right after prolonged nitric-hydrofluoric acid etch. (Courtesy Armco Steel Corp.)

to nitric-hydrofluoric acid at 175 F for three 4-hr. periods. This acid solution generally produces a vigorous intergranular attack even on areas containing only a small number of scattered intergranular carbides. As shown by the results in Figs. 3 and 4, Types 304 and 316 underwent severe intergranular attack in this corrosive medium, while the low-carbon steels show no evidence of sensitization from welding. Similar results were obtained for ½-in. plate.

A striking comparison of the susceptibility of low- and regular-carbon materials to corrosive attack on the heat-affected weld zone is shown in Fig. 5. Two ⅛-in. sheets, one of Type 304 and containing about 0.06% carbon, and the other of LC-304 with 0.03% carbon, were welded together and immersed five days in nitric-hydrofluoric acid at 140 F. Localized corrosive attack on the heat-affected zone of the 304 base metal was so strong that the specimen was almost severed at that area.

These results have been generally verified by nitric acid tests carried out on weld seam specimens. In one series of tests, welded specimens of LC-304, LC-316 and their higher carbon counterparts were immersed in boiling 65% nitric acid for five 48-hr. periods. Although appreciable intergranular attack occurred in the heat-affected zone of the 304 and 316 base metal, no such localized attack resulted in the low-carbon steels.

In another series of tests, welded specimens of low- and regular-carbon 304, 316, 347 and columbium-stabilized 316 were subjected to nitric acid in the as-welded and in the welded and stress-relieved conditions. The stress relief treatment was 2 hr. at 1600 F. As before, LC-304 was generally superior to its higher carbon counterpart in resistance to intergranular corrosion. In both nitric and sulfuric acid tests, the resistance of LC-304 was not impaired even by slow cooling from the stress-relieving temperature. In addition, both the low- and regular-carbon types of 347 exhibited satisfactory corrosion resistance in as-welded and in welded and stress-relieved conditions. Here it should be pointed out that use of the terms "satisfactory" and "unsatisfactory" in this article is based upon a common acceptance level of 0.002-in. penetration per month. LC-316 was equal or superior in its corrosion resistance to regular-carbon 316 after welding or after air cooling from the stress-relieving temperature. After extremely slow cooling from the stress relieving temperature, however, this low-carbon material was unsatisfactory by the nitric acid test, though still satisfactory by the sulfuric acid treatment. The regular-carbon, columbium-stabilized 316 steel was satisfactory in both the welded and stress-relieved conditions, whereas the lower carbon grade was not satisfactory.

With the exception of the columbium-stabilized 316 steel, it is apparent on the basis of weld tests alone that the low-carbon stainless steels have proved equal or superior in corrosion resistance to the higher carbon materials. It should be emphasized that this conclusion is valid only for the welding conditions and heat treatments employed in the tests.

In other tests, low-and regular-carbon grades of 304, 316, 347 and columbium-stabilized 316 were heated for 2 and 24 hr. at various temperatures above 800 F before applying the nitric acid test. None of the materials heated 24 hr. demonstrated satisfactory resistance to intergranular corrosion. After the 2-hr. period, LC-304 again proved superior to its higher carbon prototype; and data on LC-347 indicated that the columbium-stabilized 18:8 material offered no advantage over LC-304. Results of nitric acid tests on the low-carbon, molybdenum-containing steels indicated, however, that neither LC-316 nor columbium-stabilized LC-316 possesses satisfactory resistance to intergranular corrosion after being heated 2 hr. at sensitizing temperatures. This susceptibility was not shown up by corresponding tests with sulfuric acid solution.

Laboratory corrosion tests are not reliable indices of service performance for conditions differing from those under which the acceptance tests are made. Nevertheless, weld corrosion tests and field experience indicate that the corrosion resistance of a low-carbon stainless steel in the as-welded condition is generally equal to that of the columbium-stabilized steel in the same condition, or to its corresponding regular-carbon grade in the welded and annealed condition. It is this practical conclusion upon which rests the utility of the low-carbon stainless steels.

Table 2—Tensile Bar Properties at Elevated Temperatures

Property	Temperature, F	304 Annealed	LC-304 Annealed	LC-304 Annealed, Heated 2 Hr. at 1600 F, Air Cooled.	316 Annealed	LC-316 Annealed	LC-316 Annealed, Heated 2 Hr. at 1600 F, Air Cooled.
Ultimate Tensile Strength, Psi.	Room	85,000	80,000	80,000	80,000	77,000	77,000
	400	70,000	60,000	62,000	78,000	63,000	63,000
	800	68,000	57,000	55,600	74,000	59,000	57,000
	1000	60,000	52,500	53,000	71,000	56,500	57,000
Yield Strength (0.2%), Psi.	Room	38,000	34,000	34,000	38,000	34,000	34,000
	400	20,000	17,000	18,000	29,000	18,500	20,500
	800	16,000	13,500	13,000	22,500	15,000	14,000
	1000	14,000	12,500	12,000	21,500	13,000	12,500
Elongation, % in 2 In.	Room	60	60	60	55	60	60
	400	55	52	57	50	51	50
	800	45	48	47	38	47	46
	1000	43	45	44	33	51	46
Reduction of Area, %	Room	70	77	77	77	70	70
	400	69	75	74	75	62	63
	800	68	68	70	68	56	58
	1000	66	67	70	62	56	57

Adapted from data furnished by Armco Steel Corp.

Acknowledgment

Most of the information in this article has been furnished through the cooperation of Armco Steel Corp. and Carnegie-Illinois Steel Corp.

Sprayed Metal Coatings Improve Corrosion Resistance of Wide Range of Products

by JOHN E. WAKEFIELD

Metallizing, well-known as a maintenance tool, is also proving useful for applying corrosion resistant nonferrous coatings in the manufacture of many products.

• THE TIME TO PREVENT corrosion is before it starts. That is why the possibility of metallizing should be considered in the original design and production of parts or products which are subject to corrosive conditions in service. Metallizing is already recognized as a valuable repair and maintenance tool, but the advantages of its use as an initial production method are not as well known. As a production method, metallizing is fast. For example, zinc can be sprayed at the rate of 55 lb. per hr. The process is adaptable to many production techniques from straight hand operation to fully automatic conveyor lines. Sprayed metals are competitive in cost with other coating methods.

Sprayed zinc, aluminum, tin and lead can be used for corrosion protection. Sprayed zinc and aluminum, particularly, offer electrochemical as well as physical protection and are the two most generally useful metals. They are both low in cost and they are both anodic to iron and steel. Porosity, which exists to some degree in all sprayed metals, is of no consequence with these two, since they seal their own pores in a short time. Both provide electrochemical protection even when scratches or other damage expose the base metal.

Methods of Application

Perhaps the best way to bring out the adaptability of the process to the initial production of products is to describe various types of actual applications now being carried out. Some are purely hand operations; others involve the use of turntables or other conveyor systems, with guns hand-held and manipulated. Some are fully automatic, even to start-stop mechanisms on the guns, to prevent loss of metal during indexing cycles. Three typical set-ups should suffice to illustrate the point.

The first and least automatic is the metallizing of vapor type degreasers with zinc. Many small units are now being coated, such as the one shown in Fig. 1. A much larger size is a 90-ft. long, 15-ft. high, straight-through unit used in automotive plants, where the shop conveyor travels right through the degreaser. All sizes are metallized by hand. First, the unit is pressure blasted with G-16 or G-18 angular steel grit, with the nozzle manipulated by hand. Then, the zinc spraying is done with hand-operated guns.

According to the latest reports, many of the principal manufacturers of vapor degreasers metallize them with zinc during fabrication. The trichlorethylene base solvents are noncorrosive, but they clean the degreasers themselves so rapidly that any exposed steel would be rapidly attacked by the atmospheric conditions in the plant, and by the acids in the oils and greases removed from the products being cleaned. Sprayed zinc prevents attack on the steel.

In degreaser work of this kind, the metallizing process demonstrates an advantage that is quite unique. Corrosive attack is apt to be more severe near the condensing level inside the degreaser, due to formation of acids there. Metallizing applies a heavier coating on that section than on the rest of the unit. It is quite an advantage to be able to coat heavier on those parts of a product which are attacked worse than others.

The second, or semi-automatic operation, is illustrated by Fig. 2. Here, aluminum railway car frames are being metallized with aluminum to prevent corrosion. The copper-bearing aluminum needed for high strength does not offer much resistance to cor-

Fig. 1—Manual method of metallizing is being used here to zinc coat a vapor type degreaser.

Fig. 2—Semi-automatic operation is being used to metallize copper-bearing aluminum railway car frames with aluminum.

Table I—Cost and Speed of Metallizing

Metal	Wire Size B.&S. Gage	Total Cost /Hr.	Cost /Lb. Sprayed	Cost /Sq. Ft. 0.010 In.	Speed Sq. Ft. Covered /Hr. 0.010 In. Thick	Deposit /Sq. Ft. /0.010 In. Thick In Lb.	Spray /Sq. Ft. /0.010 In. Thick In Lb.
Aluminum	3/16 in.	7.34	0.61	0.086	85.3	0.125	0.14
S. F. Aluminum	3/16 in.	9.10	0.57	0.08	113.8	0.125	0.14
Lead	3/16 in.	37.79	0.29	0.24	159.0	0.533	0.82
Antimony Lead	3/16 in.	40.39	0.31	0.24	166.0	0.51	0.78
Tin	3/16 in.	92.33	1.11	0.48	194.0	0.334	0.43
Zinc	3/16 in.	16.80	0.31	0.14	121.0	0.332	0.45

rosive attack. Sprayed aluminum, however, is pure and does resist attack very well.

In this installation, the heavy members are conveyed on rollers through the blast room, where nozzles are mounted to clean and roughen all faces. Then, they move on to the metallizing stations where hand-operated guns apply the sprayed aluminum. The picture shows the latter operation as carried out by the Nooter Corp. at St. Louis.

The third, and almost fully automatic set-up, is one which has received some publicity before, but it is worthy of repetition to illustrate the factors involved in automatic operation. Fig. 3 shows the indexing table used for spraying aluminum on aircraft cylinder head assemblies. Cylinders are loaded onto the table at the station barely visible at the left. From there, the table indexes to the next station, where the cylinder is revolved and given a preliminary coat of aluminum. The single gun used at this station feeds up the cylinder at an angle which permits the spray to reach one side of the fins. At the top of the stroke, the angle is reversed so that the other side of the fins is coated on the down stroke. Indexed to the third station, the cylinder revolves again, while two guns, one at an up-angle, the other slanting down, coat the barrel with the additional aluminum needed. At the next station, two guns work on the head.

Some hand work is needed to complete spraying of the head, due to its peculiar shape, which prevents the sprayed metal from reaching all surfaces. This is a touch-up station, which would likely be needed for any product with as many sides or faces as this one. However, the majority of the work here, and all of it on many products, can be done with fully automatic operations.

Speed and Cost

Metallizing has almost no practical limit of speed. To be sure, a single gun will spray only a given number of pounds of a particular metal in a given time. However, if more speed is required, it is quite a simple matter to add another gun, or several. Such a move does not, with metallizing, place a premium on space, because a complete metallizing set-up does not take much room. One present installation, for example, includes 28 guns arranged in two batteries, to spray both sides of the product. The entire set-up takes less space than a medium-sized electroplating tank, with its supplementary wash tanks, and considerably less than a hot-dip galvanizing installation.

The modern high-speed production unit uses 3/16-in. dia. wire. It is almost fully automatic in operation, through two recent developments in its mechanism. A controlled power unit, or governor on the compressed air turbine, which drives the wire feed mechanism, insures constant speed of wire feed. A siphon principle in the gas head construction makes it possible to maintain a constantly correct flame. Between the two, uniform sprayed metal coatings, with predictable characteristics, are obtained.

This particular gun sprays 55 lbs. of zinc per hr. Assuming a desired thickness of 0.005 in., the unit will coat close to 240 sq. ft. of surface per hr. It sprays aluminum at 12 lb. per hr. Again using 0.005 in. as the specified thickness, coverage will be about 170 sq. ft. an hr. Tin, having a lower melting point, sprays faster still, running to 83 lb. an hr., or, for the customary 0.020 in. thickness, close to 400 sq. ft. per hr.

It is quite difficult to discuss the cost of a production process, because there are so many variables in size, shape and quantity of product, means of handling them, etc. Furthermore, initial costs must be reconciled with desired service life, which will undoubtedly affect the amount of metal applied. Assuming certain arbitrary rates and prices, it is possible to throw some light on the subject.

For these purposes, the 5000-lb. price of 3/16-in. dia. metallizing wire, available from one of the principal suppliers, is used. Labor is figured at $1.50 an hr., acetylene at $2.50 a hundred cu. ft., oxygen at $1.00 a hundred cu. ft., and compressed air at 1¢ per hundred cu. ft. No overhead, handling or other costs are taken into account, and no allowance is made for the blast preparation. Based on these rates and prices, the cost of metallizing work with several common metals

Table II—Life Expectancy of Metallized Coatings

Corrosive Condition	5-10 Years	10-20 Years	20-40 Years	Over 40 Years
Rural Atmosphere	—	0.003 to 0.005 in. Zinc	0.005 to 0.007 in. Zinc	0.010 to 0.012 in. Zinc
Industrial Atmosphere	—	0.006 to 0.008 in. Aluminum 0.006 to 0.008 in. Zinc	0.010 to 0.012 in. Aluminum 0.012 to 0.015 in. Zinc	0.012 to 0.015 in. Aluminum 0.014 to 0.016 in. Zinc
Salt Atmosphere	0.006 to 0.008 in. Aluminum	0.008 to 0.010 in. Aluminum 0.010 to 0.012 in. Zinc	0.010 to 0.012 in. Aluminum 0.012 to 0.015 in. Zinc	0.012 to 0.015 in. Aluminum 0.014 to 0.016 in. Zinc
Fresh Water Immersion	0.006 to 0.008 in. Zinc 0.006 to 0.008 in. Aluminum	0.010 to 0.012 in. Zinc 0.008 to 0.010 in. Aluminum	0.012 to 0.015 in. Zinc 0.012 to 0.015 in. Aluminum	—
Salt Water Immersion	0.010 to 0.012 in. Zinc	0.014 to 0.016 in. Zinc	—	—

In all cases above, it is assumed that no paint is needed for appearance and that no maintenance will be necessary.

Fig. 3—A fully automatic set-up as shown here is well suited to production-line manufacturing operations.

used for corrosion protection is projected in Table I.

While costs will vary in direct proportion to the coating thickness desired, the total metallizing is not in direct proportion. Surfaces must always be prepared to receive the sprayed metal. Hence, doubling the thickness of the coating does not double the cost. For that reason, it is often desirable to apply a fairly heavy coating.

It is interesting to note, in this connection, that the service life of all zinc coatings, whether sprayed or not, is in direct proportion to the thickness of the coating. This has been clearly proved through studies of the Iron & Steel Institute and others. In other words, the heavier the zinc, the longer it will protect. Relating this information to the fact that doubling thickness does not double cost, it becomes clear that heavier coatings will frequently pay dividends.

Since preparation is a part of metallizing, some factors in its cost should be discussed. In corrosion prevention work, preparation is usually done with a pressure blast machine using angular steel grit or a good grade of hard, sharp, angular, washed sand. The choice is governed by whether the abrasive can be recovered and used again. If it can be, steel grit should be used. It produces surface which will provide a stronger bond with the sprayed metal, can be used many times, and is, therefore, generally less expensive. Sizes G-16, G-18 and G-25 are the most commonly used. If sand is selected, it should be silica or flint and of 16- to 20-mesh size.

Theoretically, it takes 10 lb. of sand or 25 lb. of angular steel grit to blast properly 1 sq. ft. of surface. Of course, surfaces having rust, dirt, oil, grease, scale or other foreign matter will take more abrasive per square foot. Assuming reasonably clean steel, the principal factors in determining blast cost are: (1) capacity of the machine; (2) size nozzle used; and (3) size of abrasive selected.

There are certain general rules that are worth keeping in mind. First, the higher the air pressure, the faster the blast operation. However, pressures much in excess of 100 psi. are apt to break down the abrasive too rapidly. Generally, too, the smaller the grit size, the faster the operation. Therefore, it is advisable to use the smallest size that will provide an adequate bond.

Here again, of course, there are many variables, in methods of handling, recovery of the abrasive, reloading of the machine, etc. Hence, it is found that the cost of preparation may vary all the way from 3¢ per sq. ft. to 10¢ or 12¢. Between these figures and those in Table I, a rough idea of metallizing costs can be obtained.

The length of service life is one of the most important of sprayed metal's advantages. A significantly old metallizing job is that on the 110,000-gal. wash water tank at the Bureau of Water, Erie, Pa., in which a 32-ft. dia., 19-ft. 3-in. deep tank is located. The inner tank was not metallized when installed and showed heavy corrosion after only 18 months in service. In May, 1934, it was sandblasted and coated with 0.006 in. of sprayed zinc. A recent inspection showed it in excellent condition.

Such a service history is not surprising in view of the results of repeated accelerated laboratory tests. In addition, exposure of test panels at Kure Beach, Long Island Sound, the Canal Zone and other test sites, has confirmed the laboratory tests. From the three sources, it is now possible to predict the service life of sprayed metal coatings in various common conditions. Table II is quite significant. It is also interesting to note the different conditions in which zinc is preferred to aluminum, and vice versa.

Design Considerations

To take full advantage of long-life, low-cost metallizing protection, many products might have to be redesigned to some extent at least. The construction of fire extinguishers in England has been quite radically changed to permit their being metallized inside. By doing so, a practical and less expensive extinguisher has been developed.

In products which are to be welded, it is sometimes desirable to use galvanized plate and spray the weld with zinc after welding is completed. This is being done on steel barrels at the present time with excellent results. In other cases, it is more practical to use plain steel and metallize the whole assembly.

For large structures, it might be well to plan for metallizing of beams or girders in a shop, where the accessibility of necessary equipment and the work itself will tend to lower costs considerably. Coatings should stop about 1 in. from an intended weld, so that the zinc or aluminum will not interfere with the operation. After erection, the joints can be sprayed, giving complete protection, and preventing the accumulation of moisture at inaccessible sections. Such a technique could be applied to many products from air conditioning equipment to bridges.

This leads naturally to a discussion of other aspects of metallizing which may help to determine its proper field of use. It is a dry process, and can be used safely on parts or products which might be contaminated by plating liquors. It is a cold process, and, therefore, useful where sections are light or complicated and might be distorted or otherwise damaged by the heat of dipping or wiping processes.

There is one other aspect that is worthy of thought. Quite a number of products are designed now with fairly heavy section, to provide adequate strength after loss of material from corrosion. Heavier, longer life coatings of sprayed metal may make it possible to lighten the sections, since very little weight or strength will be lost over a much longer period of time.

There seem to be many possibilities for the use of metallizing in connection with tumbling barrels. Some products, particularly in the hardware field, lend themselves to tumbling barrel operation. A metallizing unit can be mounted in the mouth of the barrel after blast preparation has been completed, and the parts sprayed with zinc, aluminum, tin or cadmium while they are slowly revolved and tumbled. A little work has already been done along these lines and shows great promise. For one thing, it is inexpensive. Secondly, much denser coatings result, making it possible to obtain smoother finishes and, more important still, to use thinner coatings.

New Styrene Plastics Have Improved Shock Resistance

by **KENNETH ROSE,** Western Editor, Materials & Methods

Good impact strength can now be added to the wide range of favorable properties and fabricating qualities possessed by the polystyrenes.

• THE POLYSTYRENES, one of the newer groups of plastics materials, have become one of the workhorses of the thermoplastics family within about a decade. Considerable latitude in properties, along with good fabricating qualities, have enabled this group of materials to take full advantage of the favorable price situation created by the Government's large-scale building of styrene plants to supply the wartime synthetic rubber program. Able to undersell the general-purpose cellulosics by from 5 to 15¢ per lb., polystyrenes have become general-purpose thermoplastic molding materials in their own right. Development of varieties of polystyrene having useful upper service temperature limits as much as 50 F above the working temperatures of most thermoplastics, and at only a slight premium price, has given them another edge.

A disadvantage of the polystyrenes has been their limited resistance to shock. Parts molded with thin sections have always been rather brittle, especially when the other requirements for the piece have made it impossible to formulate for improved shock resistance. The cellulosics, on the other hand, have always had good shock resistance, and for some types, such as the ethyl celluloses, shock resistance has been outstandingly good. The result has been that the cellulosics have sometimes been chosen over the polystyrenes, even at a premium price when shock resistance was a deciding requirement.

During the past year there have been announcements of polystyrenes of improved shock resistance. Typical of these are Dow Chemical Co.'s Styron 475 and Rohm & Haas Co.'s Plexene TA. The latter material possesses impact resistance equal to that of the cellulosics. Both obtain the higher impact strength at the expense of clarity.

Striking tumbler molded of one of the new styrene plastics to demonstrate its high impact strength. (Courtesy Rohm & Haas Co.)

In general, the new polystyrenes possess the following characteristics:

1. Good rigidity.
2. Excellent impact strength.
3. Good fabricating possibilities.
4. Excellent electrical properties.
5. Low water absorption.
6. Low specific gravity.

Properties of Styron 475

The composition offered by Dow Chemical Co. under the trade designation Styron 475 is suitable for injection or compression molding or extrusion. It can be worked easily without any special equipment or procedures. Molding cycles are, in general, comparable to those used for most polystyrenes, but for injection molding the injection temperature is usually about 30 to 50 F lower than for other polystyrenes. Temperatures of 400 to 450 F and pressures of 15,000 to 18,000 psi. would be good practice in general.

For compression molding the same formulation is used, and temperatures might be about 350 to 400 F, with pressures of about 1500 to 2500

psi. The parts should be permitted to cool below 160 F before being ejected from the cavity to avoid distortion and excessive shrinkage.

The new material can be extruded at equal or slightly faster rates than standard polystyrenes. The temperature of the plastic in the extruder will vary with the machine being used and with the cross-sectional area of the piece being extruded. An experimental run might be started with the material at 390 F, and the temperature varied up or down to give best operation. It is good practice to keep the die temperatures 10 to 20 F higher than extrusion temperatures to give the best surface gloss to the work. The same machines used for extruding other polystyrenes or cellulosics will be satisfactory for working impact-resistant polystyrene. Clearance between screw and cylinder should be as close as possible, and preferably less than 0.005 in. on each side. The screw should have a compression ratio of up to 3 to 1.

Impact strength of this new polystyrene is from three to five times that of standard polystyrenes, and elongation is about ten times as great as the corresponding value for the standard varieties. Dimensional stability is good. Colors are limited to opaques, but the range is wide. Surface luster is usually inferior to that of molded polystyrene, and a fine matte surface is characteristic of the molded impact-resisting type. Careful control of die temperatures is the best means of developing good surface, and 150 to 170 F seems to be the optimum range. Draft clearance in the molds can be reduced to about half of that for polystyrenes. Mold shrinkage for Styron 475 is about 0.001 to 0.003 in. per in., but the high elongation makes the lessened draft satisfactory.

Specific properties announced by the producers are given below:

Tensile strength:
- At 1% offset 3000-4000 psi.
- Ultimate 4000-5000 psi.

Elongation 20-34%

Impact strength (Izod):
- Notched (at 77 F) 0.8-1.2 ft.-lb./in. of notch
- Unnotched (at 77 F) 7.5-11.5 ft.-lb./in. of width

Heat distortion point 156 F, under 264 lb.

Water absorption 0.06% gain in 24 hr. at 77 F

Electrical properties:
- Dielectric constant, at
  - 10^3 cycles 2.45-2.55
  - 10^6 cycles 2.43-2.53
  - 10^8 cycles 2.41-2.51
- Power factor, at
  - 10^3 cycles 0.00025-0.00029
  - 10^6 cycles 0.00052-0.00056
  - 10^8 cycles 0.00077-0.00081

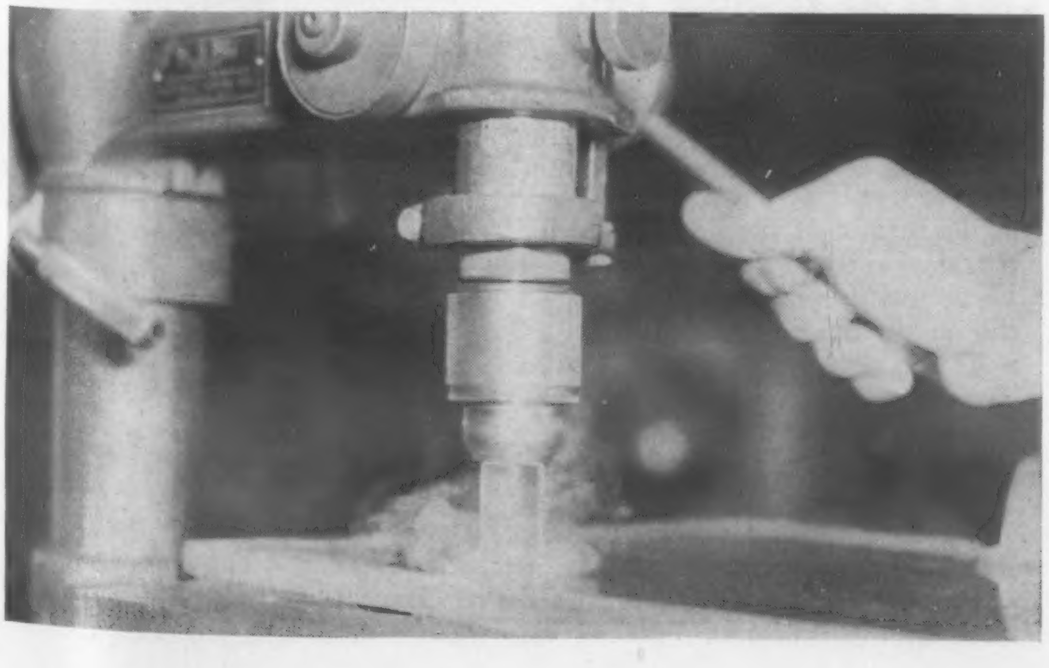
Specific gravity 1.05

Chemical properties — soluble in aromatic and chlorinated hydrocarbons, ketones, ethers. Insoluble in weak acids, alkalies, alcohols

Properties of Plexene TA

The Rohm & Haas Co.'s Plexene TA, a styrene-base copolymer, is offered as a molding powder suitable for injection molding, compression molding and extruding. It is one of several formulations, all based upon a special high-impact copolymer offered under the general designation Plexene T. Variation of properties is therefore possible by going to one of the closely similar types.

Polystyrenes have excellent fabricating characteristics in addition to their favorable service properties. (Courtesy Rochester Button Co.)



In its general properties the plastic resembles the material already described. It has high impact strength, good dimensional stability, excellent electrical properties, and good chemical properties. It works well in the presses. Colors are limited to opaques, but a wide variety, including white, can be produced.

Injection molding is best done with the cylinder temperature at about 425 F for ordinary work. If the material seems too fluid during molding, the cylinder temperature can be dropped while holding the pressure high. Difficult flow in the mold might indicate the need for higher cylinder temperature. The dies should be maintained at about 130 to 170 F.

Compression molding can be done at temperatures of about 280 F or higher and pressures of about 1000 psi. or greater. Plexene TA is intended primarily for injection molding and extruding, however.

The plastic can be extruded in standard equipment. A cylinder temperature of about 350 F is recommended by the producer, with the die at about 200 F for best surface on the extrusion.

Specific properties are given as follows:

Tensile strength 6100 psi.

Elongation 15-35%

Impact strength (Izod),
- Notched 5.0 ft.-lb./in. of notch

Heat distortion point 183 F, under 264 lb.

Water absorption 0.3% gain in 24 hr.

Electrical properties:
- Dielectric constant, at
  - 10^3 cycles 4.3
  - 10^6 cycles 3.7
- Power factor, at
  - 10^3 cycles 0.08

Specific gravity 1.06

Chemical properties — soluble in aromatic and chlorinated hydrocarbons, ketones, ethers, ethyl acetate. Insoluble in weak and moderately strong acids, alkalies, alcohols, petroleum hydrocarbons.

The new polystyrenes will be especially suited to large area moldings, such as refrigerator parts, housings for electrical appliances, and luggage; to pieces requiring high impact resistance, such as safety goggle frames, industrial containers such as tote boxes, and pens and pencils; and electrical applications, such as battery parts and cases, radios and flashlights.

Carburizing Pastes Permit Fast Low-Cost Selective Hardening

by JULIUS FISH, Denfis Chemical Laboratories, Inc.

Two special paste compounds—one for hardening, the other for insulating against hardening—provide an economical means of carburizing small quantities of parts.

• THE OBJECT OF case-hardening steel is to produce a hard surface over a tough, ductile core. This process is employed where high hardness, high strength or wear resistance are required of the surface, and it is essential for the core to be tough to resist shock or soft to permit machining. For both technical and economic reasons, it is often desirable that the case-hardening reaction be restricted to those areas of the fabricated part which require high hardness for service applications.

Heat treatable steels can often be continuously and selectively surface-hardened by automatic induction heating equipment. For steels with low carbon contents, which depend for case-hardening on chemical surface reactions and subsequent diffusion, a variety of selective methods are in use. All of these methods are costly, however, as they involve electroplating, extra machining or, at the least, additional labor cost.

The carburizing and isolating pastes can be protected by wrapping the part in sheet iron and inserting it in a tube.

Now, many of the economic disadvantages of chemical selective surface hardening appear to have been overcome through the use of a special pack hardening paste and an insulating or "isolating" paste. These pastes are available commercially under the trade names of Carburit and Isopac. Resembling putty in consistency, they are easily applied and removed. The pack hardening paste is a carbonaceous compound which is applied to the surface to be hardened. It affords a rate of carbon penetration appreciably higher than that of ordinary carburizing compounds, thus making possible significant savings in production time. Conversely, the isolating paste is used to retard the diffusion of carbon at areas where softness is desirable and to prevent subsequent hardening of those sections. This article will discuss briefly how both large- and small-scale fabricators can best secure the production advantages offered by these relatively new compounds.

How to Use Carburizing Paste

In both principle and operation, use of the carbonaceous paste amounts simply to a restricted pack hardening operation. Since the product of the chemical reaction must be deposited at the surface of the steel before the necessary diffusion can take place, it is essential that the surface be cleaned thoroughly before case-hardening.

The section to be hardened is then covered with a heavy layer of the carbonaceous paste, which should be pressed tightly on the work to assure intimate contact. Layer thickness of ½ in. is recommended; this thickness should be adequate for case depths up to at least 0.040 in. However, optimum layer thickness for different case depths is best determined by carefully controlled trials, followed by accurate case depth measurements. Here it should be mentioned that, in case-hardening exterior flat surfaces, it is often possible to effect considerable savings in the cost of the compound by sandwiching the paste between two similar parts, thus hardening both simultaneously.

The paste should be protected by wrapping the workpiece loosely in a piece of sheet iron or inserting it in a tube of appropriate diameter. The assembly is then placed in a furnace or open forge; or, if necessary, it can be heated by a gas torch. If a torch is used, special care should be taken to maintain temperature as uniform as possible. Uniform temperatures are necessary to produce uniform carburizing and hardening and to control distortion.

For a fixed case depth, temperature and time of heating are interdependent. Thus, the time required to produce a given case can be reduced by increasing the temperature. Or, conversely, the temperature necessary to produce a given case can be lowered by increasing the heating time. Selection of the proper time and temperature combination is an economic problem based upon relative heating costs. Although practical carburizing temperatures range from 1550 to 1750 F, it has been found that a temperature between 1650 and 1700 F generally gives a fair rate of carbon penetration without raising furnace costs excessively. When steels of medium carbon content (0.40% carbon, for instance) are used and a shallow case is desired to prevent brittleness, carburizing is often carried out at 1550 to 1600 F for better control of case depth.

Another variable, of less importance than time and temperature, is

the composition of the steel. As would be expected, the rate of carbon penetration is higher in low carbon grades than in medium carbon steels where a lower driving force exists. Other alloying elements affect the readiness with which carbon is absorbed in the carburizing grades of alloy steels. In addition, some steels differ in the maximum carbon concentration which can be built up at or next to the surface.

The table below lists the heating times required for a few typical case depths obtained at 1700 F:

Depth of Case, In.	*Time at Heat, Min.*
0.010	5-7
0.015	10-15
0.030	25-30

Because of the influence of the various factors mentioned previously, these heating times must be regarded only as approximate guides. Furthermore, it should be emphasized that these figures represent time at temperature; to them must be added the time required for the metal surface beneath the paste to reach furnace or flame temperature. In furnace heating an allowance of 20 to 30 min. should be made.

The next step after the heating period depends upon the type of steel used and the specific physical characteristics desired in the steel part. Generally, a coarse-grained steel must be cooled slowly from the carburizing temperature so that objectionable brittleness will not result. Plain carbon grades can be air-cooled; but moderately and highly alloyed steels having coarse grains are best cooled in the furnace. In such cases, the carbonaceous paste is allowed to remain on the surface during cooling, thus preventing decarburization. Even fine grain steels are often cooled slowly from the carburizing temperature to enable machining operations to be performed on the carburized surfaces, or, in highly alloyed steels, to prevent undue retention of austenite.

On the other hand, a fine grain steel can sometimes be direct-quenched from the carburizing temperature. A direct quench in oil produces lower and more regular distortion than slow cooling, in addition to eliminating a step in subsequent heat treatment. It is important that the pack hardening paste be removed from the part before carrying out any quenching operation; otherwise, it will insulate the surface against the quenching medium and the heat treatment will be ineffective. The heat-dried paste can be easily knocked off or removed with a wire brush before quenching.

If a part has been slowly cooled from the carburizing temperature and is to be further heat treated, it is advantageous to delay removing the paste until immediately preceding the first quenching operation. This provides further protection against decarburization of the hardened surface. In the event that a heat treatment involving more than one quenching operation is required, leaving the paste on after carburization would be of little value; ultimately, the protection afforded by a salt bath or special furnace atmosphere would be advisable.

How to Use Isolating Paste

The inert isolating paste has a dual function when used in connection with selective surface hardening. During the carburizing treatment, it retards appreciably the entrance of carbon into the surface it covers. During subsequent heat treatment, it slows the cooling rate of that section of the steel part to such an extent that only in the air hardenable tool steels can that section be hardened. An auxiliary function of the isolating paste is to prevent scaling and decarburization. Therefore, it is important that the isolating paste be applied tightly to a clean surface so that no air pockets remain between the paste and the work. If the work is to be casehardened in a salt bath, it should be heated after application of the isolating paste in order to dry the paste thoroughly before immersion.

Optimum thickness of the isolating paste layer varies with both the case depth being produced and the hardenability of the steel. However, a thickness of ½ in. appears to be adequate for all applications. It is clear that, in cases where the paste is used for the sole purpose of preventing scaling or decarburization, and hardening of the steel is desired, the paste must be removed before quenching. This can easily be done in a manner similar to that employed in removing the carburizing paste. Otherwise, on sections desired soft, the isolating paste should be allowed to remain until the heat treating cycle is complete.

Advantages and Limitations

The principal advantage offered by carburizing and isolating pastes is simplicity of equipment and technique. To realize the extent of this advantage it is necessary only to consider briefly the alternate methods of selective surface hardening.

This gear was hardened with the carburizing paste, the inner surface being kept soft with the isolating paste.

Isolating paste was used to keep the narrow section on the left and the inside of the holes soft while the piece was hardened in a salt bath.

In pack carburizing, for instance, it is possible to pack the part in sand, exposing only the desired surface areas to the carburizing compound. In addition, there are two general procedures which are used in connection with pack, gas or liquid carburizing. One of these techniques involves leaving extra stock on the workpiece where softness is desired after carburizing, then machining off the undesirable carbide layer. The other method consists of protecting the areas to remain soft with copper. In some cases these areas can be protected by various copper forms, such as tubing, cups, sleeves, disks, washers, etc. A more usual approach is to employ an electrodeposited copper plate. Here, two alternate techniques are used. The whole surface can be plated, the copper then being machined off the areas to be carburized. Or, those sections to be carburized can be protected against electrodeposition by a coating of lacquer before being immersed in the copper plating bath.

The lacquer burns off at carburizing temperatures.

It is not difficult to see the economic limitations of these procedures. The labor cost involved in pack carburizing has always been high; the necessity for packing the workpiece selectively in two mediums pushes this cost still higher. The other methods involve additional machining costs, the expense of maintaining a special inventory of standard copper forms or of fabricating special copper forms, or the power and equipment expense of electroplating.

Although the large fabricator, equipped with salt baths and atmosphere furnaces, would not be likely to make use of the less easily controlled open forge or gas torch for case-hardening operations, such flexibility is important to the small fabricator. It frees the small shop from the production tie-ups that sometimes result when tools wear down and have to be sent out for repair.

Of considerable importance to both large and small fabricators, however, is the production time saved as a result of the high rate of carbon penetration offered by the pack hardening paste. Ordinarily, a heating period of about 2 hr. at 1700 F is required to produce a carburized case depth of 0.030 in. As indicated by the figures given previously, this pack hardening paste produces a similar case in about ½ hr., a time saving of 75%. Consideration of the time necessary to bring the steel to heat and cool it afterward, of course, reduces appreciably the apparent proportionate time saving. Moreover, the high cost of the pack hardening paste is a factor which should not be overlooked; such a paste could never replace the relatively cheap, reusable carburizing compounds used in ordinary pack hardening. In selective hardening, however, the high cost of the pack hardening paste is easily compensated by savings in heating, equipment and labor expense and production time. The isolating paste is relatively inexpensive so that cost of that compound is not an important factor.

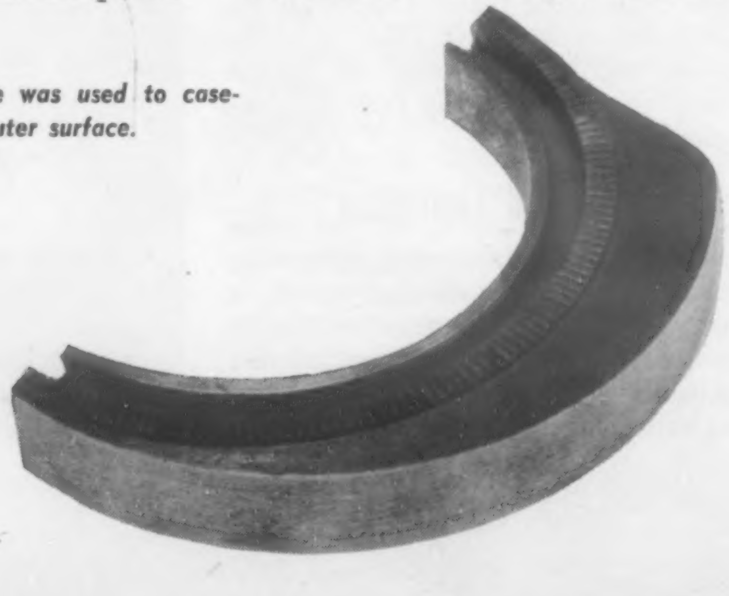
In addition to economic advantages and limitations, there are certain technical characteristics of these compounds which should be considered. Use of the pack hardening paste produces a case which tapers off gradually into the soft section. The tolerance which should be allowed for this taper is roughly equivalent to the depth of the case, so that for the average case it would be a maximum of 0.04 in. Usually such a small tolerance can be disregarded, but where a sharp corner is to remain soft, even this small overlapping of the case can prove detrimental. In such instances, the selective method which involves machining off extra stock after carburization is believed to be the most reliable as it provides a sharply defined case.

On the other hand, it should be pointed out that the isolating paste makes possible certain results that could not previously be guaranteed by some of the other selective methods. Copper forms are often ineffective because the lack of a tight bond permits the carburizing gases to enter beneath the copper. Adequate protection by electrodeposited copper depends upon such close control of variables during plating that in many plants an effective plate is not achieved. Even the isolating paste, in common with other commercial pastes now available, does not adequately prevent the diffusion of carbon into the surface which it covers. It is effective only for fairly shallow cases; generally it only retards carbon pickup. But, by slowing the cooling rate and thus preventing the subsequent hardening of the section it covers, the paste, unlike other commercial materials, eliminates the detrimental effects of the added carbon. As mentioned previously, this advantage does not apply to air hardening steels. Although the consistency of the isolating paste is such that its application is slower than that of materials which can be sprayed on, the technical advantages mentioned above compensate for this slight additional expense.

Applications

Present and potential applications for selective surface hardening techniques are almost innumerable. In general, selective hardening is used when certain portions of the surface are to remain soft to control distortion, increase toughness, or to permit machining, polishing or straightening. Gears, camshafts, dies, valves and valve seats are just a few types of parts which are selectively hardened to great advantage. Some of the parts which have been successfully hardened selectively through use of the pack hardening and isolating pastes are illustrated in the accompanying photographs. Field reports indicate that the carburizing paste is particularly useful in hardening relatively inaccessible surfaces such as the base of a blind hole. An important use of the isolating paste is to protect threaded sections during carburizing operations.

The adaptability to mass production methods offered by induction heating has made it an increasingly popular process for selective surface hardening. However, since maximum hardness obtainable depends primarily upon carbon content, it is apparent that where extremely high surface hardness is desired, the induction heating process must be confined to those applications in which a high carbon core is not detrimental. The broad field of application for case-hardened components having low carbon cores has led to the development of automatic mechanisms for pack, liquid and gas carburizing. Used in conjunction with these modern furnace and salt bath installations, the isolating paste makes available a high-production, selective case-hardening procedure. For small production runs, either the carbonaceous or the isolating paste can be used, depending upon the relative area and location of the surface to be hardened and the equipment available. Use of the pack hardening paste in mass production would appear to be feasible only if the surface to be hardened were so located that the parts could be quickly and easily inserted in a layer of the paste. In effect, then, these pastes allow the fabricator to (1) adapt high-production carburizing methods to selective surface hardening; and (2) selectively case-harden small quantities of parts with a minimum investment in equipment and labor.



Here the carburizing paste was used to case-harden only the outer surface.

Materials & Methods Manual

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This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and application

Beryllium Copper

by John T. Richards, Design Engineer, The Beryllium Corporation

Beryllium copper alloys by virtue of their versatility are finding increased use in a wide range of industrial applications. Their ease of forming, combined with their good mechanical and electrical properties, suit them for springs of many types, cams, bushings, molds for plastics, a variety of mechanical parts, and other similar products too numerous to mention. This manual is a comprehensive treatment of the subject of beryllium copper. It describes in detail the properties, characteristics and available forms of the various alloys. It also discusses design considerations and methods of forming, casting and heat treating. Finally, it lists throughout typical applications for which beryllium copper is particularly well-suited.

Contents

Introduction

Beryllium copper, by virtue of its versatility, is finding increased use in a variety of industrial applications. Through heat treatment, this material offers a wide range of useful properties. In the heat-treatable condition, beryllium copper is ductile and can be severely formed to meet the most exacting design requirements. A simple low-temperature heat treatment doubles the strength and hardness and, at the same time, substantially increases electrical and thermal conductivity. In addition, this alloy is nonmagnetic and offers good resistance to corrosion, wear, fatigue and moderately elevated temperatures.

There are available several alloys—each age-hardenable and each offering a different combination of properties. Although generally considered precipitation-hardening, beryllium copper, unlike certain aluminum alloys, does not age at room temperature but requires artificial aging in the range of 550 to 900 F. In color, these alloys vary from copper to gold, depending upon composition.

At the present time beryllium copper is furnished in wrought, cast or forged form. Wrought products include strip, rod, bar, wire and tubing; and sand, pressure, investment, plaster and permanent-mold castings are available. Furthermore, the designer can choose from one or more tempers to meet specific requirements.

By virtue of excellent elastic and endurance strength combined with good formability and unexcelled resistance to anelastic behavior, beryllium copper is used extensively for mechanical and current-carrying springs as well as diaphragms, bellows, bourdon tubes and other pressure responsive elements. Other wrought applications include resistance welding electrodes, cams, bearings, bushings and similar components. Castings find use as molds for plastics, resistance welding dies, heavy-duty switches and a wide variety of mechanical parts.

Beryllium copper alloys can be fabricated by standard production methods. Strip can be readily blanked, formed, deep drawn or spun, while rod and bar respond to hot or cold forming methods, including forging, machining, swaging, etc. In addition, parts can be joined to other beryllium copper components or dissimilar metals by soldering, brazing or welding.

Classification of Available Materials

Beryllium copper alloys can be grouped as (1) high strength or (2) high conductivity. High strength alloys (over 1% beryllium) offer maximum strength and hardness, while high conductivity alloys (under 1% beryllium) find use where electrical and thermal conductivity are of greater importance than maximum strength. Table I lists nominal compositions.

25 Alloy is the standard wrought beryllium copper material of 2% nominal beryllium content which combines good electrical conductivity with the highest strength and hardness of any copper alloy when heat treated. By virtue of its excellent resistance to fatigue, corrosion and wear, this nonmagnetic material is ideally suited for springs, diaphragms, bellows, electrical contacts, aircraft engine parts, cams, bearings and resistance welding electrodes (RWMA Class 4), including flash welding dies. This alloy meets the composition and mechanical property requirements of the specifications included in Table II. Revision letters and date suffixes, which frequently change, are not listed.

165 Alloy is a lower beryllium-content version of the standard 2% material (25 Alloy) and offers good formability in the unhardened condition with high final properties following aging. This alloy is also available as mill-hardened strip, which without heat treatment reaches strengths and hardnesses appreciably higher than bronze. Through good formability it presents cost-saving opportunities by eliminating hardening.

10 Alloy is a high-conductivity material having moderate strength which finds use in current-carrying springs, switch parts and similar components where good electrical and thermal conductivity as well as excellent resistance to moderately elevated temperatures are required. Since this material has good formability and machinability when heat treated, it is generally supplied in this condition, requiring no heat treatment by the fabricator.

50 Alloy is a high-conductivity alloy especially designed for resistance welding electrodes (RWMA Class 3). By virtue of its good conductivity and hardness as well as low surface-contact resistance, this alloy is used for spot, seam, flash and projection welding dies and electrodes.

20C Alloy is the casting version of the standard 2% alloy which offers special advantages for sand, investment and plaster-mold casting through good fluidity, low pouring temperatures and high final properties after hardening. Applications include bushings, cams, marine propellers, pump parts, bearings, gears, safety tools and valve parts. This is the most universally employed beryllium copper casting material. The others are of more limited application. For precision casting work, 20C Alloy meets the requirements of Navy Specification 46C11.

275C Alloy is a special purpose foundry alloy designed for plastics molds and other applications requiring maximum strength, hardness and wear resistance.

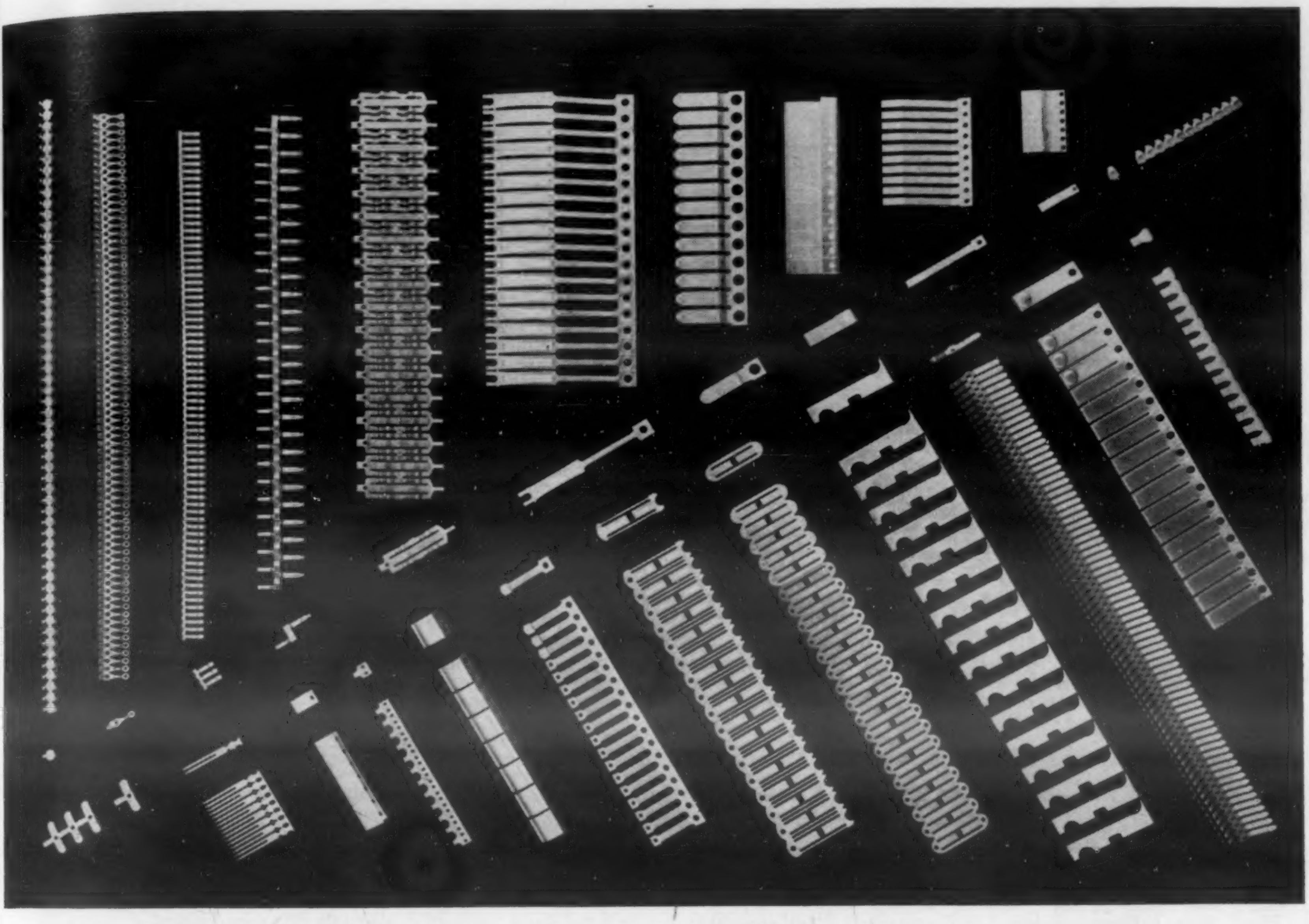
10C Alloy is a high-conductivity casting alloy especially suited for switches, circuit breakers, switchgear, welding jaws, resistance welding dies, electrode holders and similar current-carrying members where strength, conductivity and resistance to wear and moderately elevated temperatures are important.

Table II—25 Alloy Meets the Following Specifications

Authority	Specification	Forms Covered	Tempers Covered
American Society for Testing Materials	B194 B195 B196 B197	Strip Strip Rod & bar Wire	All All All All
Army-Navy Aeronautical	AN-C-166 AN-C-167	Rod, bar & wire Strip	All All
Military	MIL-C-947	Strip, rod, bar & wire	All
Society of Automotive Engineers (Aircraft Material Specifications)	AMS-4530 AMS-4532 AMS-4650 AMS-4725	Strip Strip Rod, bar & forgings Wire	Solution-annealed ½ Hard Solution-annealed Solution-annealed

Table I—Nominal Compositions (%) of Several Beryllium Copper Alloys

	Wrought				Cast		
	High Strength		High Conductivity		High Strength		High Conductivity
	25	165	10	50	20C	275C	10C
Beryllium	1.90-2.15	1.60-1.80	0.45-0.60	0.25-0.50	2.00-2.25	2.60-2.85	0.55-0.70
Cobalt	0.25-0.35	0.25-0.35	2.35-2.60	1.40-1.70	0.35-0.60	0.35-0.65	2.35-2.60
Silver	—	—	—	0.90-1.10	—	—	—
Copper	Balance	Balance	Balance	Balance	Balance	Balance	Balance



Typical assortment of "strip springs" of beryllium copper. Formed in strips, they are later separated. (Courtesy Instrument Specialties Co., Inc.)

Available Forms and Conditions

Beryllium copper alloys are generally available in the forms shown in Table III, although other shapes and finishes are furnished to meet special requirements.

As used herein, "condition" refers to the state in which the material is supplied by the mill, whether unhardened or aged. Wrought products are furnished in the heat-treatable, mill-hardened, pretempered or heat-treated conditions. Heat-treated stock is heat-hardened by the mill for maximum strength and hardness, while mill-hardened strip and pretempered wire are given special mill treatments to meet specific requirements. Castings are also available in one or more conditions. Table IV correlates mill treatment and fabricating steps by user with condition for beryllium copper wrought and casting alloys.

Table III—Available Forms

Form	25	165	10	50	20C	275C	10C
Cold Rolled Strip	X	X	X	—	—	—	—
Flat Wire	X	—	X	—	—	—	—
Rectangular Bar	X	—	X	X	—	—	—
Square Bar	X	—	X	X	—	—	—
Cold Drawn Round Rod	X	—	X	X	—	—	—
Hexagonal Rod	X	—	X	X	—	—	—
Square Bar	X	—	X	X	—	—	—
Wire	X	—	X	—	—	—	—
Hot Rolled Round Rod	X	—	X	X	—	—	—
Square Bar	X	—	X	X	—	—	—
Rectangular Bar	X	—	X	X	—	—	—
Turned Round Rod	X	—	X	X	—	—	—
Billets	X	X	X	X	—	—	—
Forgings	X	—	X	X	—	—	—
Welded Tubing	X	—	—	—	—	—	—
Seamless Tubing	X	—	—	—	—	—	—
Casting Pigs	—	—	—	—	X	X	X
Sand Castings	—	—	—	—	X	X	X
Pressure Castings	—	—	—	—	—	X	—
Plaster-Mold Castings	—	—	—	—	X	X	X
Investment Castings	—	—	—	—	X	X	X

Temper Selection

Strip is generally supplied in either the solution-annealed or one of several solution-annealed and cold rolled tempers. Available tempers for high-strength alloys are given in Table V, while minimum forming radii for heat-treatable and mill-hardened strip are included in Table VI.

Since high-conductivity (10 Alloy) strip has good formability after heat treatment, it is generally furnished in the hardened condition requiring no heat treatment after forming. For certain applications requiring severe deformation, such as drawing, heat-treatable material should be specified to be fully fabricated in the unhardened condition prior to heat treatment. Minimum forming radii for this alloy are given in Table VI.

Rod and Bar are available in several tempers. High strength (25 Alloy) material is supplied either solution-annealed or cold-worked. For most applications, the cold-worked temper gives best machinability, while solution-annealed is used where mod-

erate forming is required. Since high-conductivity alloys (10 and 50) can be readily machined after heat treatment, rod and bar are generally ordered in the fully hardened condition. Other tempers are specified for added formability.

Wire is normally furnished either solution-annealed or three-quarter hard, as shown in Table VII. Pretempered wire of any given size meets only one combination of properties, consequently there is no temper choice in selecting this product.

Engineering Properties

Physical Constants—Table VIII lists the more important physical constants for various beryllium copper alloys, while Table IX gives additional properties for 25 Alloy. All materials are non-magnetic, while the densities compare with those of carbon steel or copper. The relatively low melting ranges simplify foundry work.

Electrical and Thermal Characteristics—Both electrical and thermal conductivity increase substantially during heat treatment. Maximum conductivity is reached by overaging (aging at higher temperatures or longer times than necessary for peak hardness). Table X shows typical values for heat-treated material.

Mechanical Properties—Typical mechanical properties, including ultimate tensile strength, elongation and Rockwell hardness, are listed in Table XI for strip, rod, bar, wire and castings. Fig. 1, which illustrates the cumulative effect of cold work and aging upon 25 Alloy, indicates that it is advisable to use the highest temper consistent with formability in order to take full advantage of the available properties in this alloy.

Miscellaneous properties such as torsional, shear, compressive and impact strength are included in Table XII, while Ericksen Cup Test data are illustrated in Fig. 2 (25 Alloy strip).

Elevated-Temperature Characteristics—Fig. 3 shows the loss of hardness of several spring materials held for 1 hr. at various elevated temperatures. These curves indicate maximum service temperatures for alloys in an unstressed condition. Similar curves are shown in Fig. 4 for casting materials held at temperature for 15 hr.

In springs and similar applications, where external loading causes a stressed condition, operating temperatures are limited by relaxation. Relaxation is the loss of load with time in a constantly deflected spring and is caused by the reduction in elastic strength with increased temperatures. The relaxation curves of Fig. 5 indicate that maximum service temperatures should be limited to 300 to 400 F, depending upon alloy, unless some allowance is made in design stresses.

Fig. 6 shows the effect of time and temperature on the tensile strength of beryllium copper and several other materials in wire form. These tests point out the danger of designing on the basis of short-time tensile tests where time is a factor.

Low-Temperature Properties—Low-temperature properties for 25 Alloy are given in Fig. 7. Retention by beryllium copper of its ductility at subzero temperatures prevents impact strength reduction or low-temperature embrittlement.

Endurance and Corrosion-Fatigue—Table XIII shows the endurance strength of beryllium copper in various forms. Where applicable, the limits shown can be increased up to 100% by shot blasting followed by stress relieving (½ hr. at 400 F). Fig. 8 compares the resistance offered by various alloys to corrosion fatigue.

Corrosion—In general, beryllium copper resists corrosion in a manner similar to other high-copper alloys. Under normal conditions it offers good resistance to rural and marine atmospheres, fresh and salt water, most alkaline solutions, and some acids. Although beryllium copper alloys will in time stain and darken like copper when exposed to humid or sulfur-bearing atmospheres, tarnish does not noticeably affect mechanical properties. The resistance offered to warm and humid air indicates good service in tropical environments.

Beryllium copper has poor resistance to certain compounds of ammonia, sulfur and mercury. In acids, its behavior greatly depends upon oxidizing conditions, comparing with deoxidized copper in this respect. Increases in temperature, concentration, aeration and agitation usually accelerate corrosion, often to a rather high degree.

Combinations of either static or dynamic loading with corrosion are not harmful, unless beryllium copper is subject to direct chemical attack by the corrosive media in an unstressed condition. Consequently, stress-corrosion cracking (season cracking) is not a factor, while the combined action of corrosion and alternating stress (corrosion-fatigue) has no effect upon normal endurance properties, as shown in Fig. 8. In addition, this material has relatively good resistance to salt water cavitation or erosion.

Dezincification and hydrogen embrittlement apparently do not occur. Because of the high volatility of beryllium halides, beryllium is lost from the surface of the alloy when exposed to halogens (fluorine, chlorine, bromine and iodine). Since this is especially true at elevated temperatures,

Table IV—Beryllium Copper Alloys Supplied in the Following Conditions

Alloy	Form	Condition	Temper	Mill Treatment	Fabricating Treatment
25	Strip	Heat treatable	Sol.-annealed ¼ Hard ½ Hard Hard	Sol.-annealed Sol.-annealed and cold-rolled	Fabricate and heat treat
	Rod Bar Wire	Heat treatable	Sol.-annealed Hard	Sol.-annealed Sol.-annealed and cold-worked	Fabricate and heat treat
	Wire	Pretempered	—	Heat treated and cold-drawn	Fabricate
165	Strip	Heat treatable	Sol.-annealed ¼ Hard ½ Hard Hard	Sol.-annealed Sol.-annealed and cold-rolled	Fabricate and heat treat
		Mill hardened	Sol.-annealed ¼ Hard ½ Hard Hard	Sol.-anneal and mill harden Sol.-anneal, cold roll and mill harden	Fabricate
10	Strip Rod Bar	Heat treatable	Sol.-annealed Hard	Sol.-annealed Sol.-annealed and cold-worked	Fabricate and heat treat
		Heat treated	Sol.-annealed Hard	Sol.-annealed and heat treat Sol.-annealed, cold-worked and heat treated	Fabricate
50	Rod Bar	Heat treated	Hard	Sol.-annealed, cold-worked and heat treated	Fabricate
20C 275C 10C	Cast	Sol.-annealed	—	Cast and sol.-annealed	Fabricate and heat treat
		Heat treated	—	Cast, sol.-annealed and heat treated	Fabricate

Table V—Temper Selection for High-Strength Strip (Alloys 25 and 165)

Temper	Cold-Rolled Reduction in B&S Numbers	ASTM Designation	% Reduction in Thickness	Relative Formability
Sol.-Annealed	0	A	0	Best for deep-drawn, cupped or severely formed parts
¼ Hard	1 No. Hard	¼ H	11	Almost as formable as sol.-annealed stock and gives better spring properties
½ Hard	2 No. Hard	½ H	21	Moderate formability with good strength for parts incorporating liberal radii or light drawing
Hard	4 No. Hard	H	37	Max. mechanical properties with reduced cold-forming characteristics for parts essentially flat

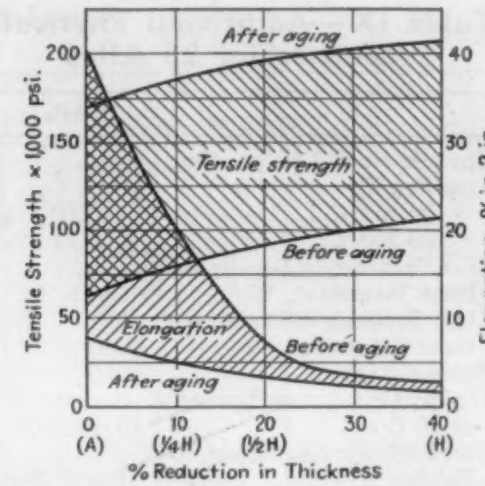


Fig. 1—Effect of cold rolling and age hardening on the tensile strength and elongation of beryllium copper strip.

Table VI—Minimum Forming Radii for Strip
(Up to 0.040 In. Thick)

	Ratio of Inside Radius to Thickness for a 90-Deg. Bend				
	25	165	165	10	10
	Heat Treatable	Heat Treatable	Mill Hardened	Heat Treatable	Heat Treated
Sol.-Annealed	Any	Any	1	Any	3
¼ Hard	1	1	2	—	—
½ Hard	2	2	3	—	—
Hard	5	5	6	3	5

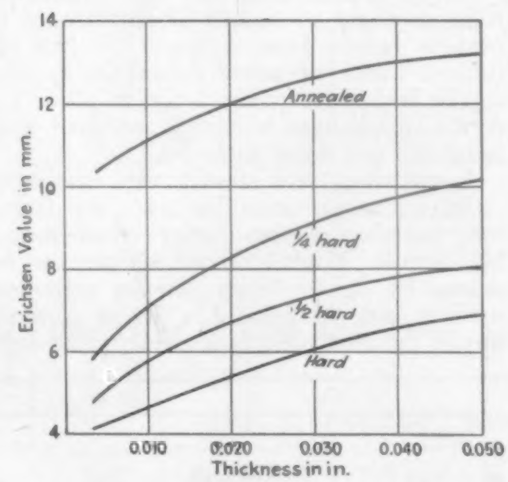


Fig. 2—Typical Erichsen cup test values for 25 Alloy strip.

Table VII—Temper Selection for 25 Alloy Wire

Temper	Mill Treatment	ASTM Designation	% Reduction in Area
Sol.-Annealed	Cold drawn and sol.-annealed	A	0
¾ Hard	Cold drawn, sol.-annealed and drawn 3 No. Hard	¾ H	50

beryllium copper should not be used where exhaust gas from bromine-treated tetraethyl lead gasoline is present.

Table XIV, which gives general corrosion data for direct chemical attack, is intended only as a rough guide. Whenever possible, tests should be conducted under actual operating conditions.

Design Considerations—The engineering properties of beryllium copper shown herein result from tests conducted under inspection or laboratory procedures, so that some care should be exercised in attempting to incorporate these values in design work. Safe working stresses depend not only on the material used, but also on type of load (static or endurance) and operating conditions. In addition, design stresses derived from engineering properties should be used only where the part can be readily subjected to stress analysis.

For static loads, the stress will be limited by the amount of offset or permanent set permissible in the application—never by the ultimate strength. When no regularly measurable deviation from the elastic condition is allowable, working stresses must be kept below the proportional limit. When space permits, a maximum design stress of at least 10,000 psi. below the proportional limit is recommended to insure positive action in statically loaded parts.

Table VIII—Typical Physical Properties for Material in the Heat Treated Condition

	25	165	10	50	20C	275C	10C
Specific Gravity	8.26	8.26	8.75	8.75	8.09	8.09	8.62
Density, Lb. per Cu. In.	0.298	0.298	0.316	0.316	0.292	0.292	0.311
Magnetic Properties	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic	Non-magnetic
Melting Range, F	1600-1800	1600-1800	1885-1955	1850-1930	1600-1800	1570-1660	1885-1955
Elastic Modulus in Tension, Psi.	19,000,000	18,500,000	18,000,000	18,000,000	18,500,000	19,000,000	17,000,000
Thermal Expansion Coefficient							
Per Deg. C: 20-100 C	0.0000167	0.0000167	—	—	0.0000166	0.0000166	—
20-200 C	0.0000170	0.0000170	0.0000176	0.0000176	0.0000170	0.0000170	0.0000178
20-300 C	0.0000178	0.0000178	—	—	0.0000176	0.0000176	—
Per Deg. F: 68-212 F	0.0000093	0.0000093	—	—	0.0000092	0.0000092	—
68-392 F	0.0000094	0.0000094	0.0000098	0.0000098	0.0000094	0.0000094	0.0000099
68-572 F	0.0000099	0.0000099	—	—	0.0000098	0.0000098	—

Table IX—Additional Physical Properties for 25 Alloy

	25 Alloy
Specific Heat, Cal. per Gm. per Deg. C	
30-100 C	0.10
100-300 C	0.11
Max. Increase in Density on Heat Treatment, %	0.6
Max. Decrease in Length on Heat Treatment, %	0.2
Poisson's Ratio	0.30
Elastic Modulus in Tension at 20 C	19,000,000
Thermoelastic Coefficient in Tension	0.00035
Elastic Modulus in Torsion at 20 C	7,300,000
Thermoelastic Coefficient in Torsion	0.00033

Table X—Electrical and Thermal Properties of Several Beryllium Copper Alloys

	25	165	10	50	20C	275C	10C
Electrical Properties							
Conductivity— % I.A.C.S. at 20 C	22-30	22-30	48-60	50-55	20-25	18-23	45-50
Resistivity— Microhm Cm.— 20 C	7.8-5.7	7.8-5.7	3.8-2.9	3.4-3.1	8.6-6.9	9.5-7.5	3.8-3.4
200 C	9.4-6.8	9.4-6.8	—	—	—	—	—
Temp. Coefficient of Resistivity 20-200 C	0.0009	0.0009	—	—	—	—	—
Thermal Properties							
Conductivity—Btu./Sq. Ft./In./Hr./F— 68 F	750-900	750-900	1450-1800	1500-1700	650-800	600-750	1400-1600
392 F	900-1100	900-1100	—	—	—	—	—
Cal./Sq. Cm./Cm./Sec./C— 20 C	0.26-0.31	0.26-0.31	0.47-0.61	0.50-0.57	0.22-0.28	0.21-0.26	0.48-0.55
200 C	0.32-0.37	0.32-0.37	—	—	—	—	—
Temp. Coefficient of Thermal Conductivity 20-200 C	0.0012	0.0012	—	—	—	—	—

In the case of endurance loads, however, it is necessary to reduce design stresses to prevent failure from fatigue. For best results, a factor of safety should be applied to the endurance values listed to allow for corrosion, changes in section, elevated temperatures and other variables.

For springs and similar elements, adequate allowance must be made for forms that introduce higher stresses than shown by formula. High localized stresses can be caused by bends, holes, uneven clamping surfaces, etc. In general, a design formula should be used only as a guide, to be supplemented by actual tests.

Even when working stresses are within prescribed limits and ample allowance has been made for yield or fatigue, small deviations from elastic laws can be observed. Anelasticity (hysteresis, damping, creep and drift) is greatly influenced by stress and temperature, so that some allowance may be necessary in critical applications. Fig. 9 illustrates the effect of stress upon drift in several flat spring materials.

In using beryllium copper in place of some other material, it is generally not advisable to make a direct substitution. To utilize fully the properties available in beryllium copper, parts should be redesigned to allow for changes in modulus, allowable stress, conductivity, etc.

Casting and Forming Characteristics

Melting and Casting Practice

Beryllium copper alloys are readily melted in either electric or fuel-heated crucible furnaces. Electric furnaces of the arc or induction types provide rapid heating, minimum loss of metal, and good temperature and quality control. In using coke-, or gas- or oil-fired crucible furnaces, some care should be exercised to prevent pick-up of combustion products, since slower melting rates compared to electric furnaces mean longer exposure to contaminants.

By virtue of its good fluidity in the molten state, beryllium copper fills complicated molds at relatively low casting temperatures, providing faithful reproduction of intricate detail as-cast. The castability of beryllium copper, like most alloys, improves with increased pouring temperatures. In general, the lowest temperature that will fill the mold should be used in order to prevent excessive gas absorption or oxide formation. The pouring range for high-strength alloys (20C and 275C) generally runs 1850 to 2050 F, while the high-conductivity alloy (10C) ranges from 2050 to 2250 F.

Sand-Casting — Sand casting generally provides the most economical foundry method for producing simple shapes requiring few finishing operations. In addi-

Fig. 3—Loss of hardness for several spring materials resulting from 1 hr. at various elevated temperatures.

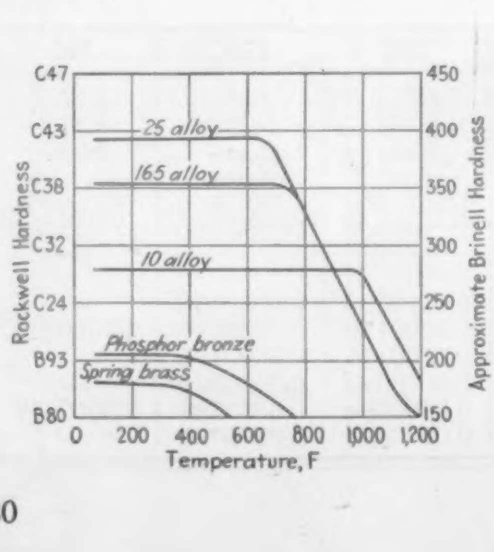


Fig. 4—Loss of hardness for several casting materials resulting from 15 hr. at various elevated temperatures.

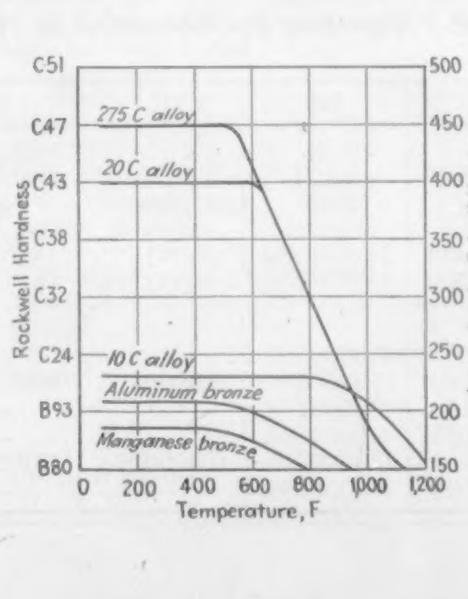


Fig. 5—Relaxation or loss of room temperature load at 50,000 psi. stress for several spring materials at various elevated temperatures.

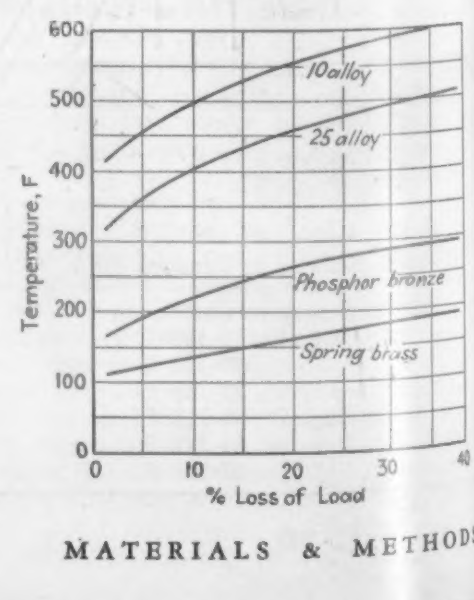


Table XI-a—Typical Mechanical Properties of Strip

Alloy	Condition and Temper	Tensile Strength, Psi.	Elong. % in 2 In.	Rockwell Hardness		
25	Sol.-Annealed	60-80,000	35-50	B45-65	30T46-60	15T75-81.5
	¼ Hard	73-88,000	10-30	B66-85	30T60.5-73.5	15T82-88
	½ Hard	80-100,000	5-10	B86-93	30T74-78	15T88.5-91
	Hard	95-120,000	2-4	B94-99	30T78.5-81.5	15T91.5-92.5
	Heat Treated from Sol.-Annealed	165-180,000	5-8	C36-40	30N56-59.5	15N78.5-80.5
	Heat Treated from ¼ Hard	175-190,000	3.5-6	C38-42	30N57.5-61.5	15N79.5-81.5
	Heat Treated from ½ Hard	185-200,000	2-4	C39-43	30N58.5-62	15N80-82
	Heat Treated from Hard	190-205,000	1-2	C40-44	30N59.5-63	15N80.5-82.5
165	Sol.-Annealed	60-80,000	35-50	B45-65	30T46-60	15T75-81.5
	¼ Hard	73-88,000	10-30	B66-85	30T60.5-73.5	15T82-88
	½ Hard	80-100,000	5-10	B86-93	30T74-78	15T88.5-91
	Hard	95-120,000	2-4	B94-99	30T78.5-81.5	15T91.5-92.5
	Heat Treated from Sol.-Annealed	150-165,000	5-8	C33-38	30N53-57.5	15N77-79.5
	Heat Treated from ¼ Hard	160-175,000	3.5-6	C35-40	30N55-59.5	15N78-80.5
	Heat Treated from ½ Hard	170-185,000	2-4	C37-42	30N57-61.5	15N79-81.5
	Heat Treated from Hard	180-195,000	1-2	C39-43	30N59-62	15N80-82
	Mill Hardened from Sol.-Annealed	100-110,000	21-30	C18-21	30N37.5-42	15N67.5-70
	Mill Hardened from ¼ Hard	110-120,000	19-25	C21-25	30N42-46	15N70-72
	Mill Hardened from ½ Hard	120-130,000	13-18	C25-29	30N46-49.5	15N72-74.5
	Mill Hardened from Hard	135-145,000	9-12	C30-33	30N50.5-53	15N75-76.5
10	Sol.-Annealed	40-55,000	25-45	B22-40	30T30.5-43	15T68-73.5
	Hard	70-85,000	5-10	B78-88	30T69-75	15T86-89
	Heat Treated from Sol.-Annealed	100-110,000	8-12	B90-95	30T76-79	15T90-91.5
	Heat Treated from Hard	105-130,000	5-10	B92-100	30T77.5-82	15T90.5-93

Table XI-b—Typical Mechanical Properties of Rod and Bar

Alloy	Condition and Temper	Tensile Strength, Psi.	Elong. % in 2 In.	Rockwell Hardness	
25	Sol.-Annealed	60-85,000	35-50	B45-80	30T46-68
	Hard	80-120,000	10-20	B80-100	30T68-82
	Heat Treated from Sol.-Annealed	165-180,000	3-10	C36-40	30N56-59.5
	Heat Treated from Hard	185-215,000	2-5	C39-44	30N58-61.5
10	Sol.-Annealed	40-55,000	20-50	B25-45	30T32.5-45.5
	Hard	65-80,000	10-30	B60-75	30T56.5-67
	Heat Treated from Sol.-Annealed	100-120,000	10-20	B92-97	30T77.5-80.5
	Heat Treated from Hard	110-130,000	8-15	B95-104	30T79-84
50	Heat Treated from Hard	110-130,000	8-15	B95-104	30T79-84

tion, it may offer the only answer for handling large parts, where sizes are limited only by existing melting and handling facilities.

Pressure Casting—The unusual combination of properties available in beryllium copper pressure castings offers significant advantages in the production of plastics and rubber molds as well as short-run die casting dies. Pressure-cast forces and cavities are employed in the injection molding of plastics and frequently prove more economical than other types, especially where multi-cavities are required.

Molds or dies are produced by pouring molten beryllium copper around a master hob and applying pressure by means of a hydraulic press while the metal solidifies. Parts have an unusually dense structure with good impact and compressive strength, high conductivity and a smooth surface. Accurate reproduction of intricate detail, thin sections, irregular parting lines, and raised letters or numbers are obtained through casting, thereby eliminating expensive machining and limiting finishing operations to liquid honing.

Investment Casting—Beryllium copper, by virtue of its relatively low pouring temperature and good fluidity, is especially adaptable to investment or "lost wax" casting. Although this process frequently presents outstanding cost-saving and design advantages, it cannot compete, price wise, with screw machine or sand cast parts requiring few finishing operations. Relatively simple or symmetrical shapes can be produced faster and cheaper by automatic machining methods; however, investment casting may offer short-run economics where screw machine parts would require special set-up or equipment.

Castings are usually limited to small sizes of intricate design, since competitive advantages of investment methods decrease as overall dimensions increase. Sand castings lack the precision or dimensional control obtainable in small investment castings, but in large parts sand castings provide equivalent accuracy at lower cost.

Where final properties may be of secondary importance, beryllium copper is frequently selected solely on the basis of its favorable casting characteristics. In contrast to high-melting alloys which require special investments and more expensive foundry equipment, the relatively low pouring temperature of beryllium copper insures economical handling. In addition, good castability offers design advantages, so that thin sections, small or blind holes, narrow slots, long cores, knife edges, and smooth surfaces over relatively large flat areas can be readily produced.

The 2.0% beryllium-content material (20C Alloy), which meets the requirements of Navy Specification 46C11 covering precision castings, has been found to offer the best combination of properties. This alloy is available in 3-oz. pigs, which are especially convenient in the small batch melting generally used in this work. Pouring temperatures in the range 1850 to 1950 F generally give good results. Although heated molds offer no particular advantage, centrifugal casting is recommended, since it provides sounder castings than gravity pouring methods.

Table XI-c—Typical Mechanical Properties of Wire—Alloy 25

Condition and Temper	Tensile Strength, Psi.	Elong. % in 2-In.
Sol.-Annealed	58-78,000	35-50
¾ Hard	110-140,000	2-4
Heat Treated from Sol.-Annealed	165-180,000	2-5
Heat Treated from ¾ Hard	185-220,000	1-3
Pretempered	145-180,000	1-4

Table XII-a—Miscellaneous Properties of Wrought Alloys

	25		165		10		50
	Annealed and Heat Treated	Hard and Heat Treated	Annealed and Heat Treated	Hard and Heat Treated	Annealed and Heat Treated	Hard and Heat Treated	Hard and Heat Treated
Tensile Properties							
Ultimate Tensile Strength	165-180,000	185-210,000	150-175,000	170-195,000	100-120,000	110-140,000	110-140,000
Proportional Limit (0.002% Offset)	70-80,000	95-130,000	60-75,000	85-120,000	50-60,000	60-80,000	70-90,000
Elastic Limit (0.002% Permanent Set)	75-85,000	100-135,000	65-80,000	90-115,000	55-65,000	65-85,000	75-95,000
Yield Strength							
(0.01% Offset)	85-95,000	120-150,000	75-85,000	110-140,000	60-70,000	75-90,000	85-100,000
(0.20% Offset)	130-150,000	160-185,000	120-145,000	150-175,000	70-90,000	100-120,000	100-120,000
(0.50% Strain)	85-95,000	85-95,000	85-95,000	85-95,000	70-80,000	80-95,000	80-95,000
Torsion Properties							
Proportional Limit	—	65-80,000	—	—	—	—	—
Compressive Properties							
(0.1% Set)	—	180-200,000	—	—	—	100-110,000	—
(1.0% Set)	—	200-220,000	—	—	—	—	—

Table XII-b—Miscellaneous Properties of Casting Alloys

	20C	275C	10C
	Annealed and Heat Treated	Annealed and Heat Treated	Annealed and Heat Treated
Tensile Properties			
Ultimate Tensile Strength	155-170,000	170-185,000	90-100,000
Proportional Limit (0.002% Offset)	80-110,000	85-115,000	50-65,000
Yield Strength (0.01% Offset)	100-115,000	105-125,000	60-70,000
(0.20% Offset)	130-155,000	140-165,000	75-85,000
(0.50% Strain)	80-95,000	80-100,000	70-85,000
Elongation % in 2 In.	1-5	1-5	3-15
Rockwell Hardness	C38-45	C42-48	B95-100
Compressive Properties			
(0.1% Set)	150-175,000	190-210,000	100-110,000
(1.0% Set)	—	210-230,000	—

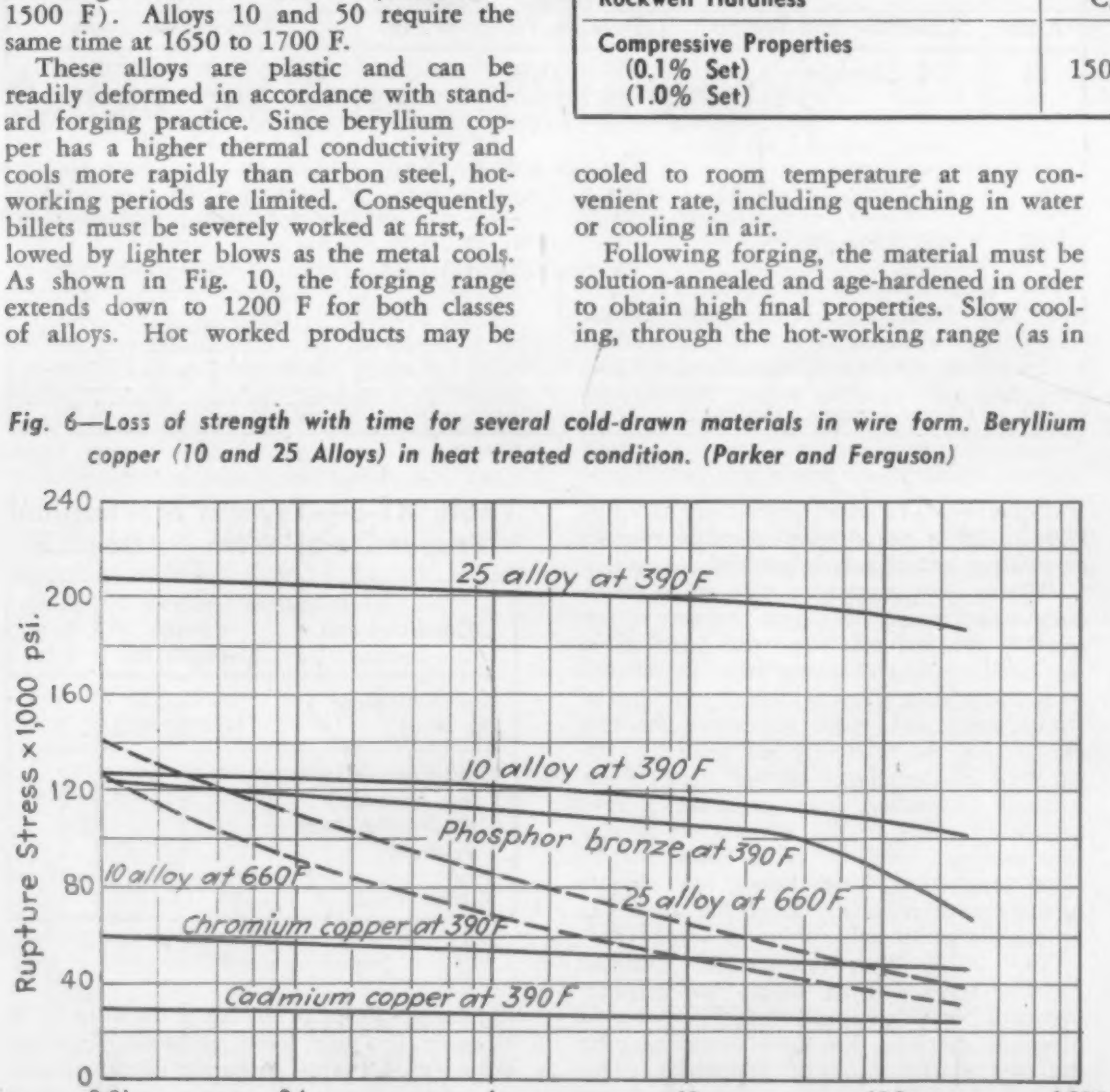
Hot Forming

Beryllium copper alloys can be hot worked by rolling, forming, pressing or forging to give a high degree of strength and toughness. High-strength forgings (25 Alloy) find use as safety tools, bushings and other mechanical parts, while high-conductivity materials (Alloys 10 and 50) are forged into seam welding disks and resistance welding dies and electrodes. Coke, gas or oil furnaces can be used for heating. The high-strength alloy (25) is generally allowed to soak for 3 to 4 hr. in the range 1450 to 1475 F (never over 1500 F). Alloys 10 and 50 require the same time at 1650 to 1700 F.

These alloys are plastic and can be readily deformed in accordance with standard forging practice. Since beryllium copper has a higher thermal conductivity and cools more rapidly than carbon steel, hot-working periods are limited. Consequently, billets must be severely worked at first, followed by lighter blows as the metal cools. As shown in Fig. 10, the forging range extends down to 1200 F for both classes of alloys. Hot worked products may be cooled to room temperature at any convenient rate, including quenching in water or cooling in air.

Following forging, the material must be solution-annealed and age-hardened in order to obtain high final properties. Slow cooling, through the hot-working range (as in forging), causes partial decomposition of the solid solution, so that solution-treating is necessary to insure subsequent hardening. Typical properties of solution-annealed and aged 25 Alloy forgings follow: tensile strength—185,000 psi., elongation in 2 in. —5%, and Rockwell hardness—C42.

Fig. 6—Loss of strength with time for several cold-drawn materials in wire form. Beryllium copper (10 and 25 Alloys) in heat treated condition. (Parker and Ferguson)



Cold Forming

Prior to heat treating, beryllium copper strip can be readily cold worked by rolling, pressworking or spinning to give a wide variety of useful components. In the unhardened condition, rod or bar can be cold formed or swaged, while wire can be bent, coiled, upset or cold headed.

Since beryllium copper work hardens faster and to a higher level of strength and hardness than other copper-base alloys, some allowance must be made for this effect during cold working. Fig. 11 compares the work hardening characteristics of several metals and alloys.

In blanking, strip which has been cold rolled (1/4, 1/2 or Hard tempers) is preferred over annealed material, since it tends to give a cleaner blank with reduced burr. For all tempers, a close tolerance (5 to 6% of stock thickness over the diameter of the blank) is necessary to limit die wear and work hardening. To prevent galling, dies must be hard and highly polished. Cadmium-plated strip gives increased die life and, at the same time, provides added lubrication. Soap and soap-fat emulsions of

approximately 15 to 20% concentration serve as lubricants for pressworking.

Beryllium copper can be readily bent or formed in accordance with the minimum forming radii given in Table VI. For applications requiring severe forming of high strength alloys, a low temper must be used, but where little or no forming is needed a high temper is suitable. Since the properties of all alloys are improved by cold work before hardening, it is advantageous to use the highest temper that the forming operation will permit. As previously pointed out, high-conductivity materials are generally supplied fully heat treated, since all but the most severely formed parts can be handled in this condition.

Fig. 7—Low temperature properties of cold worked and heat treated 25 Alloy.

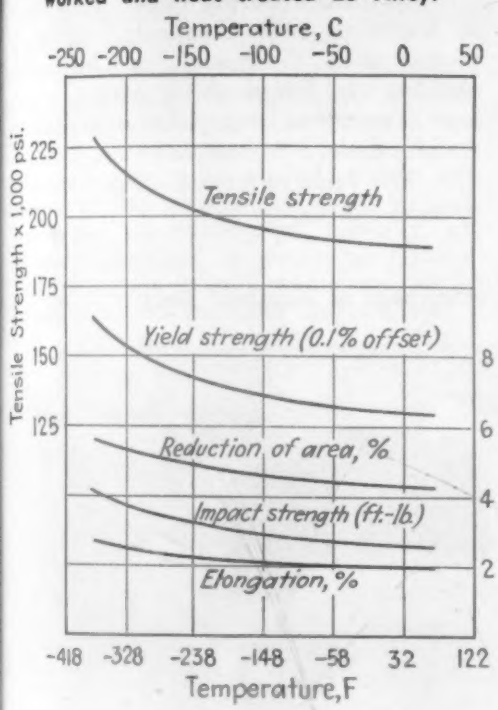


Fig. 8—Relative corrosion-fatigue of several materials in salt spray.

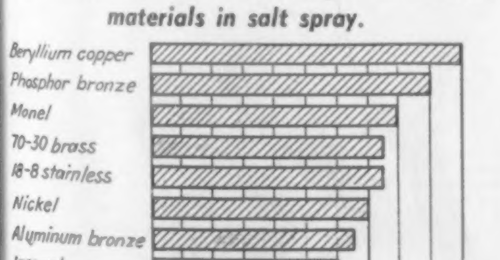
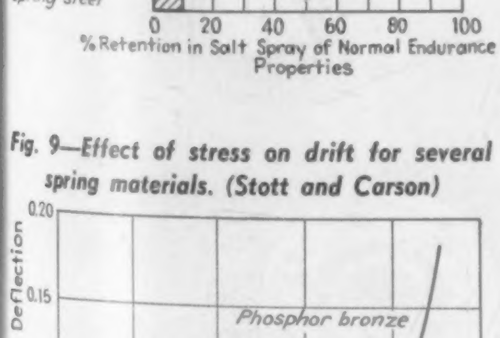


Fig. 9—Effect of stress on drift for several spring materials. (Stott and Carson)



Grain direction is generally not a factor in forming and blanking beryllium copper, because strip is not as severely cold worked as might be necessary to attain spring properties in other copper-base alloys which are not heat treatable. The absence of pronounced grain direction in the softer tempers gives almost equal strength and formability in all directions and permits economical use of stock.

In general, pressworking of beryllium copper is similar to that of phosphor bronze or spring brass of higher temper. For example, ½ Hard (2 B&S No.) beryllium copper in the heat-treatable condition has approximately the same tensile strength, elastic limit, hardness and elongation as Extra Hard (6 B&S No.) phosphor bronze A; consequently, die design, working pressure and springback are roughly equivalent.

In drawing, the temper depends upon the depth of the draw. For light work, such as diaphragms with shallow corrugations, it is frequently possible to use ¼ or ½ Hard strip; however, for deep drawing, solution-annealed material must always be used. Fig. 2, which plots Ericksen Cup Test data against strip thickness, indicates relative drawability.

In critical applications grain size may be a factor, since fine grained material has reduced ductility, while a coarse grained structure, although ductile, tends to stretch rather than flow in the die, leaving a rough surface. A rule of thumb calls for a grain size in millimeters approximately three times strip thickness in inches for light gage stock.

Rapid work hardening limits the depth in drawing beryllium copper. The diameter of a brass cup can be reduced 40 to 50% during drawing, whereas the reduction in beryllium copper is limited to approximately 30%. Where excessive depths are required, it may be necessary to include an intermediate anneal between successive drawing operations.

Although any type of press can be used, a hydraulic press offers certain advantages. The slower forming rate, together with closer control over forming pressure, insures a more uniformly drawn product. Furthermore, it is sometimes possible to draw cups or similar shapes by a hydraulic press which would not be possible to handle in a power press.

Punch and die design for drawing beryllium copper follows brass or phosphor bronze practice. There is sometimes a tendency during drawing to plate copper on the die; however, this can be avoided by suitable drawing lubricants and cadmium-plated strip. Pressure pads must be carefully adjusted to avoid wrinkling in the rim during drawing.

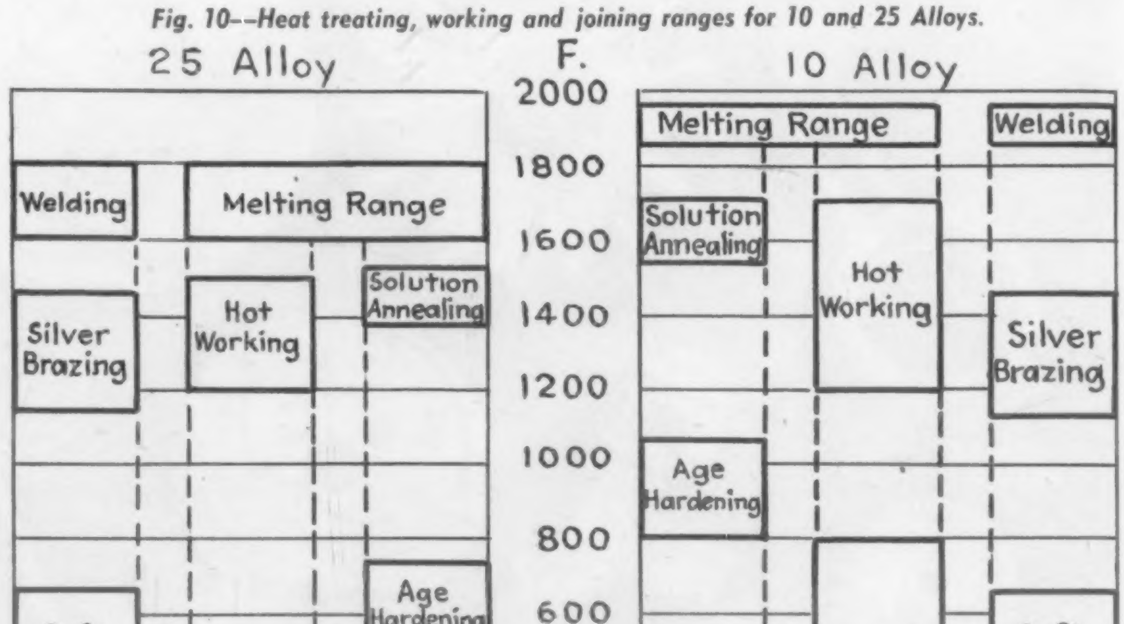
An effective, low-cost tooling development for producing diaphragms forms the material between a steel half-die and a rubber backing. This technique, good for either short or production runs, eliminates the expense in matching the two halves of a steel die. Consequently, die construction is simplified, especially for diaphragms designed with concentric corrugations where the complete die can be turned on a lathe.

Compression, extension or torsion springs can be either mandrel-coiled on a lathe or produced on regular spring coiling machines. In the case of mandrel-coiling, springs can be heat treated on the mandrel to unusually close tolerances. Pretempered wire is frequently preferred for automatic coiling, since it precludes the necessity of heat treating.

Machining

Beryllium copper is not a free cutting material but can be readily machined with proper tools, cutting fluids, speeds and feeds. On the basis of machining characteristics, this alloy can be classed with such non-leaded materials as phosphor bronze, nickel silver, silicon bronze, cupro-nickel

Fig. 10—Heat treating, working and joining ranges for 10 and 25 Alloys.



and certain grades of aluminum bronze.

In the high-strength alloys, the cold-worked tempers (rolled or drawn) offer best machinability for most turning, threading, tapping, shaping, planing, milling, sawing and screw-machine operations. Annealed material is recommended for drilling and reaming, while finish-grinding and polishing should follow heat treating. Certain forms, including castings and large rod or bar, are available only as solution-annealed; consequently, they must be machined in this condition. For high-conductivity alloys (10 and 50), all machining operations can be performed in the heat-treated condition. Although high strength materials can be machined in the age-hardened condition, this practice is not recommended for production work.

Solution-annealed beryllium copper is rather soft and gummy, not unlike copper; however, it work hardens rapidly and, in this respect can be compared with phosphor bronze or 18:8 stainless steel. Because of this tendency, the depth of cut should always be great enough to get under the work-hardened layer. The same applies for material covered with oxide, since either the scale should be removed by pickling or the tool should be kept well below the surface.

Joining Practice

Beryllium copper can be satisfactorily joined by soft soldering, silver brazing, carbon-, metal- or inert-arc and resistance welding; however, suitable methods have not been developed for bronze brazing or gas-fusion welding. All joining operations —except soft soldering—precede heat treating, because the temperatures involved are sufficiently high to rapidly soften beryllium copper (see Fig. 10).

The relatively high electrical and thermal conductivity can be a factor in brazing and welding this alloy, especially in joining with materials of decreased conductivity. Furthermore, some allowance might be necessary in considering components of varying sections. In all cases, joints should be made at points of low stress concentration.

Scale formed during either the solution or hardening heat treatments must be removed from the joint area. Mechanical cleaning can frequently be used to advantage in supplementing pickling. In addition, surfaces should be free from oil, grease or dirt. The value of a clean surface cannot be stressed too highly.

Typical beryllium copper, sand, pressure, plaster-mold and investment castings for wide range of industrial parts.

Soft Soldering

Soft soldering offers, perhaps, the easiest method of joining beryllium copper components, because working temperatures are low and soldering can follow heat treating without affecting final properties. This method offers good results where maximum strength is not required or where strength is furnished by mechanical means and solder serves principally as a means of sealing.

Tin-lead (50 Sn-50 Pb) solder finds widest use; however, antimonial-tin (95 Sn-5 Sb) or lead-silver (97.5 Pb-1.5 Ag-1.0 Sn) solders may be required for work at moderately elevated temperatures. Satisfactory heating methods include soldering iron, gas-air torch and oxyacetylene torch. For best results, joint or solder thicknesses should average 0.005 in.

When parts can be cleaned following soldering, active fluxes, such as zinc chloride or combinations of zinc, ammonium and stannous chloride, should be used. When components cannot be washed, a rosin flux must be used to prevent corrosion. Surfaces inaccessible for subsequent cleaning are frequently pretinned to insure good joints. Once parts have been tinned, they can be readily joined on any later occasion with a non-corrosive rosin-in-alcohol flux. Pretinning can be accomplished by iron or torch, hot-dipping and plating.

Silver Brazing

Although working temperatures (1145 to 1475 F) are considerably above the hardening range and will rapidly soften beryllium copper, silver brazing provides a convenient joining method if certain precautions are observed. Material softened during soldering can be subsequently heat hardened to approximately peak properties.

Compared to soft soldering, silver brazing offers higher strength at room and moderately-elevated temperatures. Tests conducted on brazed and hardened butt joints show strengths up to 90,000 psi., considerably higher than obtainable through soft-soldering. In addition, operating temperatures for silver solders permit working up to 400 F. Considerable care is required, however, in brazing strip thinner than 0.020 in. to insure proper aging, so that soft soldering may offer the only answer in handling light gages.

Lap joints, which provide greater strength than butt or scarf joints, should be used wherever permitted by design. Best results are obtained by 0.001 to 0.003-in. clearances, since capillary action insures good penetration by the molten silver alloy. Entrapped flux, poor surface condition or incomplete solder penetration are the chief causes of joint failure.

Arc Welding

Arc welding provides a high-strength method for joining beryllium copper parts or repairing worn forgings and castings. Through heat treating, joint strengths of the order of 135,000 to 150,000 psi. can be obtained with beryllium copper filler rod.

For carbon-arc welding, a d.c. welding machine capable of at least 40 v. is necessary. Straight (negative) polarity should be used, with the carbon rod (ground to a conical taper) negative and the work positive. The carbon size depends upon welding current and the electrode diameter. Beryllium copper, aluminum bronze or silicon bronze filler rods can be used; however, only beryllium copper gives a weld material that approaches the base metal in strength and conductivity. Although not always necessary, a brazing flux will generally stabilize the arc and improve the flow metal. Following welding, the assembly should be solution-annealed at 1450 F for 3 hr., quenched in water, cold peened and hardened at 600 F for 3 hr. In addition, wire brushing and peening between deposits is helpful.

Beryllium copper can be metal-arc welded using aluminum bronze electrodes. D.c. machines are employed using reverse (positive) polarity with the work negative and the electrode positive. Metal-arc welding is similar to carbon-arc practice. Heavy sections should be preheated, while metal is deposited by stringer or weave bead methods. The arc should always be directed to the beryllium copper.

Resistance Welding

Beryllium copper can be resistance welded to other beryllium copper parts or dissimilar materials by spot, seam or flash-butt methods. Although similar in weldability to cartridge brass or phosphor bronze, beryllium copper requires higher currents, shorter times and less pressure than mild steel. The detrimental effects of high electrical and thermal conductivity upon weldability can be reduced through high welding current and short weld time.

Resistance welding produces a heat-affected zone adjacent to the weld, so that some allowance should be made for this area of decreased strength, ductility, and resistance to shock or impact. In contrast to strain-hardening materials, however, part of the original strength can be restored through heat treating. Although beryllium copper can be readily resistance welded in any condition, unhardened material generally gives better results because of reduced conductivity. Whenever possible, joints should be heat treated or, better yet, solution-annealed and heat treated.

Water-cooled dome electrodes of chromium copper (RWMA Class 2) are recommended, since they provide the required

Table XIII—Typical Endurance Properties

	25		10	20C	10C
	Annealed and Heat Treated	Hard and Heat Treated	Hard and Heat Treated	Annealed and Heat Treated	Annealed and Heat Treated
Endurance Strength at 10,000,000 Load-Cycles:					
Strip—in Reverse Bending	35-45,000	40-50,000	30-35,000	—	—
Rod—					
Rotating Beam	55-70,000	55-70,000	40-45,000	—	—
Reverse Torsion	—	25-40,000	—	—	—
Wire—					
Rotating Arc	—	45-60,000	—	—	—
Casting—					
Rotating Beam	—	—	—	20-30,000	15-20,000

Table XIV—Approximate Corrosion Resistance of Beryllium Copper

Good Resistance	Fair Resistance	Poor Resistance
Acetate solvents	Acetic acid, cold, aerated	Acetic acid, hot
Acetic acid, cold, unaerated	Acetic anhydride	Ammonia, moist
Alcohols	Acetylene	Ammonium hydroxide
Ammonia, dry	Ammonium chloride	Ammonium nitrate
Atmosphere, rural, industrial, marine	Ammonium sulfate	Bromine, aerated or hot
Benzine	Aniline	Chlorine, moist or warm
Borax	Bromine, dry	Chromic acid
Boric acid	Carbonic acid	Ferric chloride
Brine	Copper nitrate	Ferric sulfate
Butane	Ferrous chloride	Fluorine, moist or warm
Carbon dioxide	Ferrous sulfate	Hydrochloric acid, over 0.1%
Carbon tetrachloride	Fluorine, dry	Hydrocyanic acid
Chlorine, dry	Hydrochloric acid, up to 0.1%	Hydrofluoric acid, concentrated
Freon	Hydrofluoric acid, dilute	Hydrogen sulfide, moist
Gasoline	Hydrofluosilicic acid	Lactic acid, hot or aerated
Hydrogen	Hydrogen peroxide	Mercuric chloride
Nitrogen	Nitric acid, up to 0.1%	Mercury
Oxalic acid	Phenol	Mercury salts
Potassium chloride	Phosphoric acid, unaerated	Nitric acid, over 0.1%
Potassium sulfate	Potassium hydroxide	Phosphoric acid, aerated
Propane	Sodium hydroxide	Picric acid
Rosin	Sodium hypochlorite	Potassium cyanide
Sodium bicarbonate	Sodium peroxide	Silver chloride
Sodium chloride	Sodium sulfide	Sodium cyanide
Sodium sulfate	Sulfur	Stannic chloride
Sulfur dioxide	Sulfur chloride	Sulfuric acid, aerated
Sulfur trioxide	Sulfuric acid, unaerated	Sulfurous acid
Water, fresh or salt	Zinc chloride	Tartaric acid, hot or aerated

conductivity, offer advantages in aligning and cleaning, and are less likely to stick to the work. Weld times are relatively short and must be closely controlled, so that electronic tube timing controls are suggested. Similarly, pressure is critical and must be carefully controlled to prevent excessive porosity or sheet distortion.

In addition, seam welding gives good results with strip, while flash-butt methods can be utilized for joining rod, bar, strip and wire when facilities permit adequate control over time, pressure and current. Dissimilar metals can also be resistance welded; however, it may be necessary to compensate for difference in conductivity between unlike materials.

Inert Arc Welding

Inert-gas-shielded arc welding offers numerous advantages in joining beryllium copper and has been successfully applied to the production of welded tubing and similar applications. A blanket of inert argon gas prevents oxidation by excluding air from the weld area, and the possibility of corrosion from entrapped flux is eliminated, since no flux is necessary. This high-speed joining method concentrates heat in a narrow zone, thereby reducing distortion and loss of strength in areas adjacent to the weld.

Alternating current, by providing optimum oxide dispersal and shallow penetration, is recommended. The tendency of surface oxide to rectify alternating current has been eliminated by the development of balanced-wave circuits. Current requirements range from 1.5 to 2.0 amp. per mil (0.001 in.) of metal thickness, while argon flow depends upon welding current, welding machine and electrode holder. Current density should be as high as possible without melting the electrode. Polished or centerless-ground tungsten electrodes are preferred.

Filler rod is not necessarily required; however, when used, 10 to 15-deg. uphill welding is suggested. Unsatisfactory welds result when molten filler metal is superimposed on unfused metal surfaces.

Heat Treating

Since the excellent properties of beryllium copper are obtained only through heat treating, it is important that the correct heat treatment be chosen. Quenching from the solution-annealing range, which softens the material, followed by treatment at a lower temperature, which hardens these alloys, permits forming of intricate shapes in the soft condition followed by hardening to maximum properties.

Although age-hardening is the result of a two-step thermal treatment, the fabricator will ordinarily be concerned only with the low temperature hardening operation, because the first step (solution-anneal) is carried out by the mill prior to shipment. For certain special applications, such as deep drawing, it may be necessary to provide an intermediate anneal, since beryllium copper, like other alloys, hardens with cold work.

The cumulative effect of solution-annealing, cold-working and age-hardening for 25 Alloy are illustrated by Fig. 12, while recommended heating times and temperatures for the various alloys are listed in Table XV.

In addition, castings and forgings are generally solution-treated prior to hardening. Although moderate properties are obtainable in castings by heat treating from the as-cast condition, maximum properties are available only through the two-step operation consisting of solution-annealing and age-hardening.

Solution-Annealing

The solution treatment serves the dual purpose of softening the material for further cold working and forcing the beryllium into solution so that it is available for subsequent hardening. Rapid quenching in water from the annealing range is necessary to retain this structure at room temperature.

For most applications, relatively small grain sizes present the most favorable combinations of engineering properties. Although low annealing temperatures can be depended upon to restrict grain size, care should be exercised to insure a high degree of beryllium solubility. Short times at high temperatures in the annealing range generally give good solubility but with larger grain size.

Table XV is intended as a guide in establishing solution-annealing procedures. Since heat-treating facilities vary considerably from one plant to the next, it is not possible to suggest annealing times and temperatures to meet all requirements.

Any type of furnace covering the temperature ranges shown in Table XV is suitable; however, salt baths should not be used, since most salts attack beryllium copper rather rapidly at temperatures in the solution-annealing range. Parts should be free from dirt, oil or grease when placed in the furnace, while cadmium plate should be stripped prior to annealing.

When additional processing follows, the oxide film formed during heating can be removed by pickling or can be prevented by bright annealing in moisture-free atmospheres of cracked ammonia, hydrogen or city gas having a dew point of at least -40 F. Where it is not possible to attain this dew point requirement, it is preferable to anneal in an uncontrolled atmosphere, such as an open gas-fired or electric furnace, causing a black oxide coating which can be readily removed by pickling.

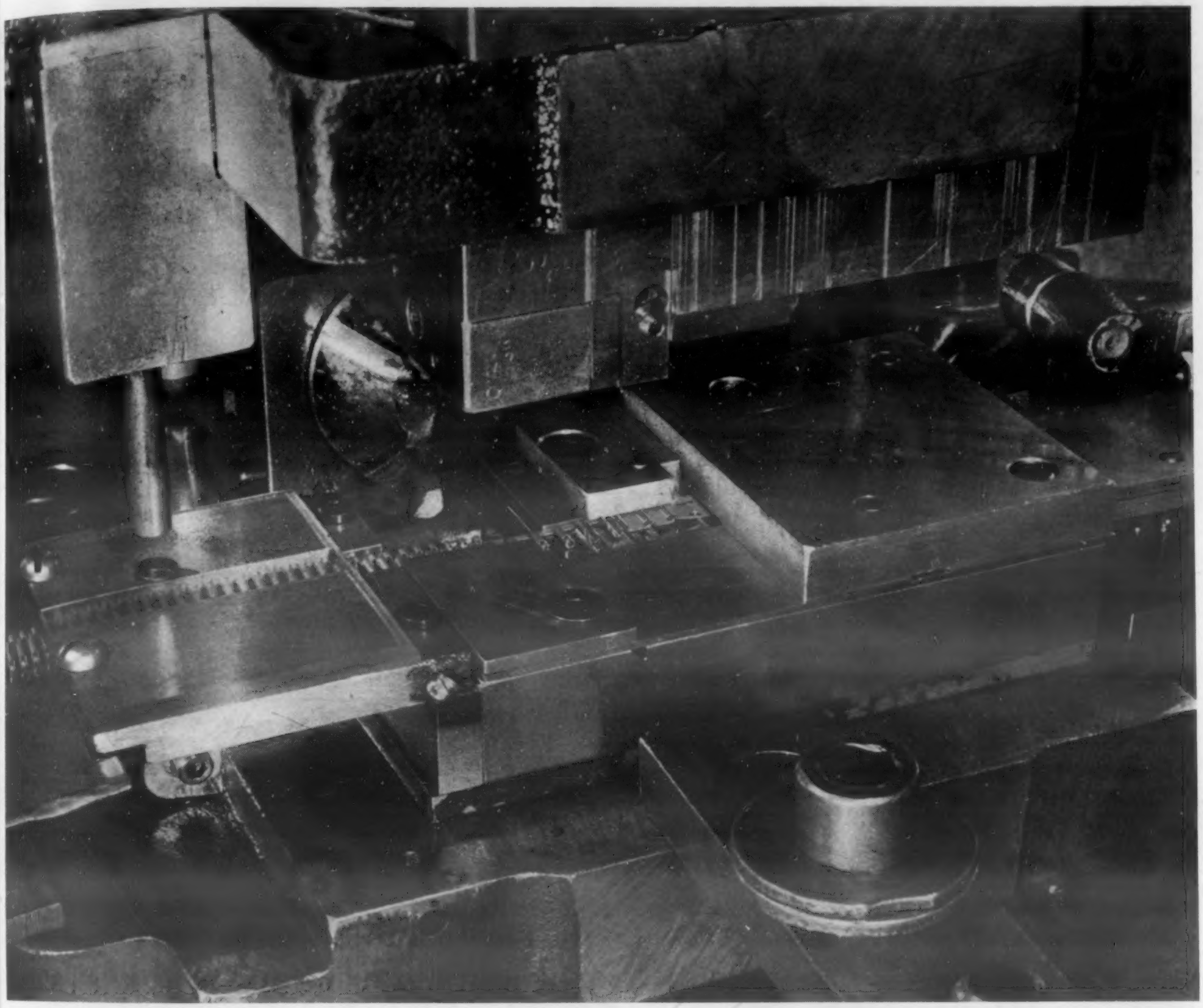
Age-Hardening

The age-hardening feature of beryllium copper offers design advantages not available in alloys that are not responsive to heat treatment. In addition, many strain hardening materials may require stress-relieving; however, beryllium copper can be stress relieved in its hardening range, so that no special operation is needed. An important advantage of beryllium copper over certain other age-hardening alloys is its simple heat treatment which can be carried out at relatively low temperatures in an uncontrolled atmosphere without subsequent controlled cooling.

It is of significance that by varying

Table XV—Recommended Heat Treating Practice

	Solution-Annealing		Age-Hardening		
Alloy	Time at Temperature	Cooling	Temper	Time at Temperature	Cooling
25	1 hr. per in. or fraction of in. of section thickness at 1450 F	Quench in water	Sol.-annealed Cold-worked	3 hr. at 600 F 2 hr. at 600 F	Any convenient rate
165	1 hr. per in. or fraction of in. of section thickness at 1450 F	Quench in water	Sol.-annealed Cold-worked	3 hr. at 650 F 2 hr. at 650 F	Any convenient rate
10	1 hr. per in. or fraction of in. of section thickness at 1700 F	Quench in water	Sol.-annealed Cold-worked	3 hr. at 850-900 F 2 hr. at 850-900 F	Any convenient rate
50	1 hr. per in. or fraction of in. of section thickness at 1700 F	Quench in water	Cold-worked	2 hr. at 850-900 F	Any convenient rate
20C	1 hr. per in. or fraction of in. of section thickness at 1450 F	Quench in water	Sol.-annealed	3 hr. at 600 F	Any convenient rate
275C	1 hr. per in. or fraction of in. of section thickness at 1450 F	Quench in water	Sol.-annealed	3 hr. at 600 F	Any convenient rate
10C	1 hr. per in. or fraction of in. of section thickness at 1700 F	Quench in water	Sol.-annealed	3 hr. at 850-900 F	Any convenient rate



Progressive die for small beryllium copper stampings. (Courtesy Instrument Specialties Co., Inc.)

hardening times and temperatures, different combinations of properties can be obtained, including strength, ductility, conductivity, and resistance to impact and anelasticity. In order that full advantage can be made of available properties, the type of hardening treatment selected should be based upon the requirements of the particular application.

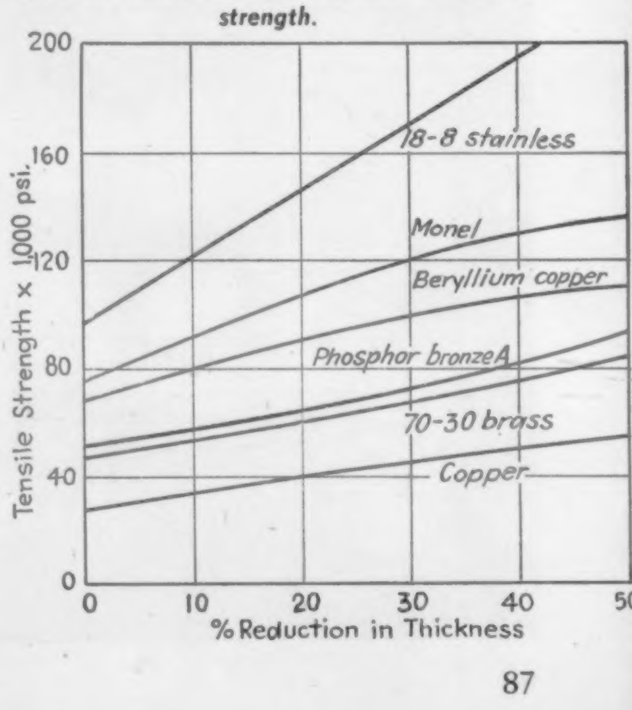
As previously indicated, strength, hardness, conductivity and modulus increase during heat treating. For a given temperature in the hardening range, these changes proceed with time; some reaching a peak and decreasing with additional time, while others continue to increase. Raising the hardening temperature reduces the time required to reach maximum strength or hardness. Fig. 13 shows the effect of time, temperature and cold work upon the tensile strength of 25 Alloy strip.

There are two types of hardening treatment in general use: (1) standard low-temperature, or (2) short-time, high-temperature. The standard low-temperature treatment is easy to control, is not critical with respect to time, and produces the highest degree of strength and hardness. For high strength alloys this heat treatment requires from 3 to 1 hr. at temperatures ranging from 600 to 650 F; for high conductivity alloys, the same time range but at 850 to 900 F. The standard heat treatment is recommended except when special properties are of greater importance than maximum strength and hardness. This treatment is also generally necessary to insure uniform heating through large sections; suggested procedure is 2 hr. or more at 600 F.

For high strength alloys the short-time, high temperature treatment requires from 90 to 15 min. at temperatures ranging from 650 to 725 F. Advantages of this method include (1) better resistance to drift and fatigue, (2) higher conductivity, (3) greater degree of stress-relief for fixture hardening and dimensional control, and (4) considerable saving in heat-treating time. This treatment is usually not applied to high conductivity alloys.

The relationship between properties attained and heating time for short-time high-temperature hardening is shown on Fig. 14. Heat treatment No. 1, through the point of peak tensile strength, gives best wear re-

Fig. 11—Work-hardening rates of several materials compared on the basis of tensile strength.



sistance and maximum hardness for the aging temperature employed. Heat treatment No. 2 provides maximum stability and should be used for critical spring and diaphragm applications requiring good resistance to drift, hysteresis and relaxation. Heat treatment No. 3 gives maximum conformity or dimensional control through a high degree of relief from internal stresses induced by cold work, causing parts to set to the shape of the fixture.

Electrical conductivity increases 50 to 100% during hardening, depending upon alloy, time and temperature. In high strength alloys, conductivity attains 20 to 33% that of copper, while high conductivity materials reach 45 to 60% conductivity. Maximum conductivity is obtained by overaging, which means heat hardening at times and temperatures greater than required for peak tensile strength. For applications requiring both strength and conductivity, a compromise time is selected.

Similarly, if added ductility is needed, some strength must be sacrificed by overaging, since ductility or elongation is at a minimum in parts hardened for maximum strength. In general, heat treating for maximum conductivity will also give increased ductility with some loss in strength or hardness. Elastic modulus, either in torsion or tension, also increases during hardening, reaching a maximum beyond the time for peak hardness. Performance tests on springs and diaphragms must be made after aging, since the increase in modulus will change the stiffness or load-deflection rate.

The best hardening time and temperature for a given combination of properties is dependent upon such variables as temper, amount of forming in making the part, and heat treating facilities. Consequently, some experimentation may be necessary to obtain special properties. This is especially true when employing the short-time, high-temperature heat treatment, which is critical with respect to time. For best results, test samples should be hardened in the same furnace, or the same type of furnace, as used for production. The times and temperatures included in Table XV apply for standard, low-temperature hardening and can be depended upon to give maximum strength and hardness.

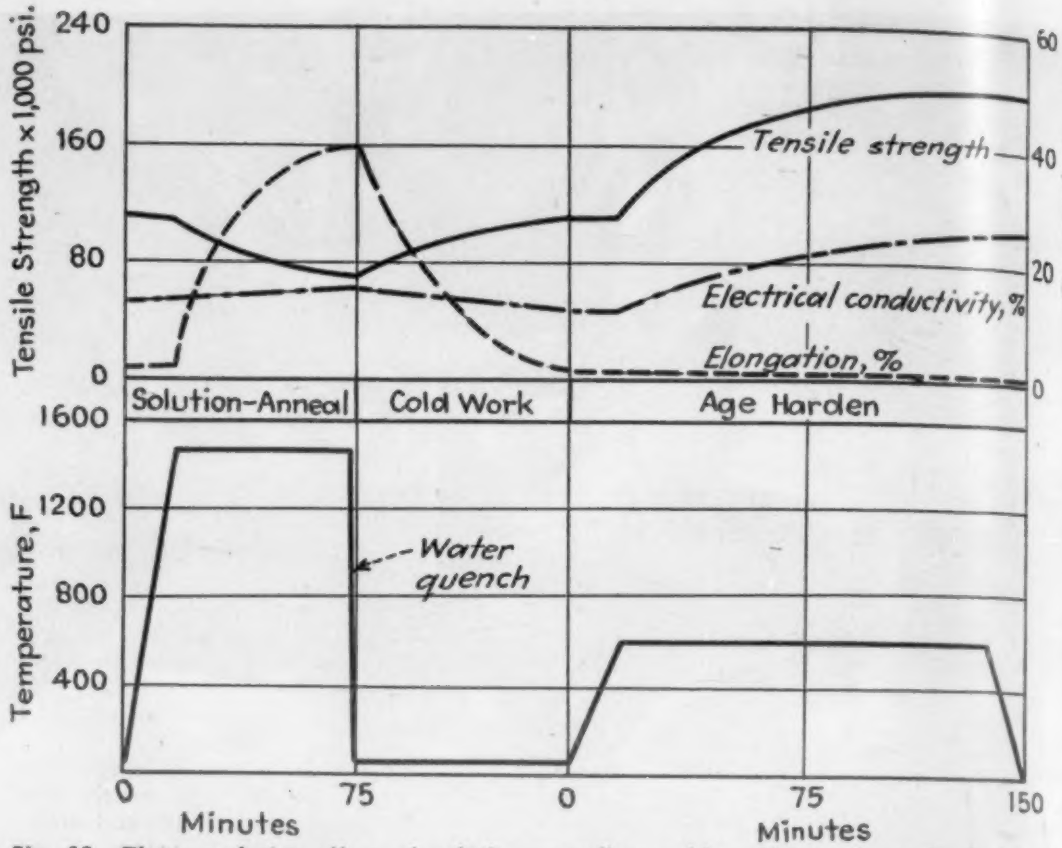
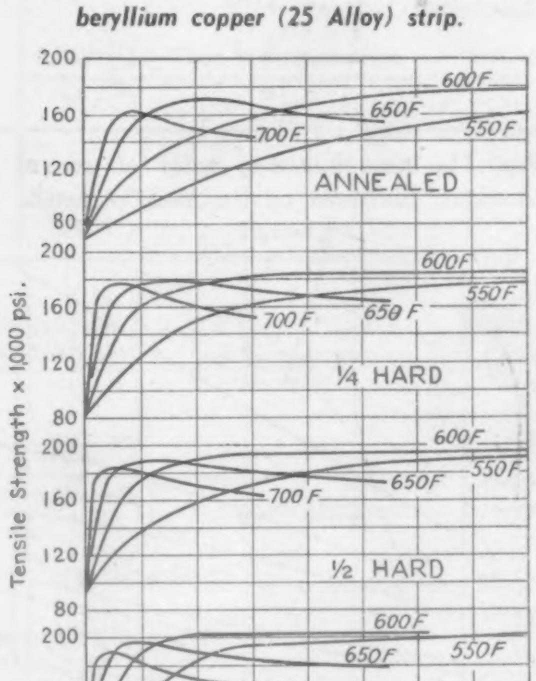


Fig. 12—The cumulative effect of solution-annealing, cold-working and age-hardening upon several properties of beryllium copper (25 Alloy).

Fig. 13—Typical age-hardening curves for beryllium copper (25 Alloy) strip.



Heat Treating Equipment

Although circulating air furnaces, muffle furnaces or salt baths are satisfactory for the standard, low-temperature treatment, short-time, high-temperature hardening requires closer time and temperature control than usually obtainable in a muffle furnace, so that a forced-circulation furnace or a salt bath is preferred. Because the heating rate is slower in a muffle furnace, hardening will require a longer time than in an air furnace. A salt bath by giving faster heat transfer requires 25 to 50% less total time than a circulating air furnace.

There are available numerous types of furnaces for heat treating beryllium copper which provide the necessary control of temperature. When hardening at 600 F, a variation of ±10 F is permissible; however, at higher temperatures this range should be limited to ±5 F. If temperature variations exist within the furnace, variations can be expected in hardness response. The thermocouple should be located so that readings will be representative of the charge. Controlled or bright atmospheres are generally not necessary, since the discoloration caused by heating in air does not affect engineering properties.

Salt baths through rapid and uniform heating give good results at any temperature in the hardening range of beryllium copper and offer special advantages for short-time, high-temperature work and fixture hardening. Commercially available nitrate-nitrite mixtures (40 to 50% sodium nitrite, balance sodium or potassium nitrate), which melt at 290 F, are usually employed. Although recommended for wrought products, some care should be exercised in attempting to handle castings in salt baths. The relatively rough surfaces, together with irregular shape, increase salt losses through drag-out, while cleaning frequently proves difficult.

For best results, a bath used for beryllium copper should be kept clean and not used for other materials such as steel. After removal from the bath, parts should be carefully cleansed of all traces of salt. Adherence to the following cleaning procedure is suggested: (1) quench in cold water, (2) wash in hot cleaning solution, (3) rinse in hot water, and (4) dry. The chocolate-colored film that remains is no way detrimental to the properties of the material and, where necessary for appearance, can be readily removed.

Parts should be both clean and free from dirt, oil, grease or moisture when placed in the furnace or bath. Following hardening, parts can be cooled at any convenient rate; however, quenching in cold water permits handling and definitely fixes the end of hardening time. For applications requiring a bright finish for subsequent processing or appearance, the oxide film formed during hardening can be removed by pickling or prevented by controlled atmosphere aging.

Through fixture hardening at a time and temperature selected to give a high degree of stress relief, beryllium copper springs and other small parts can be held to close dimensions, with variations limited only by the design and tolerances of the fixture itself. Elimination of springback and warpage makes hand adjustment during assembly unnecessary, while good uniformity over long runs entails inspection of only a small percentage of parts.

Surface Finishing

Mechanical and Chemical Cleaning

Beryllium copper products can be readily cleaned, polished or buffed in a manner similar to other copper alloys. Burrs, resulting from pressworking, can be removed from small parts by barrel tumbling, with time dependent upon the edge required. Sand blasting provides a clean uniform surface and is frequently applied to castings where a dull, rough finish is acceptable. Sandblasting precludes the necessity for pickling.

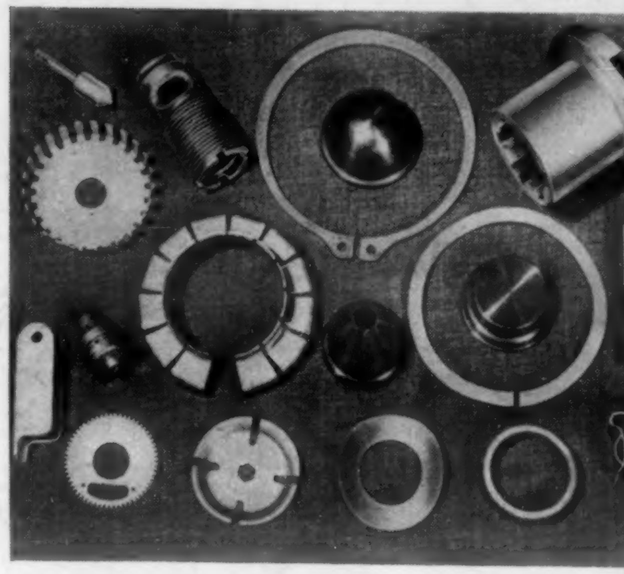
Solvent cleaning can be employed to remove cutting fluids, such as sulfurized mineral lard oils. Immediately after machining, parts should be immersed in a solvent, such as Stoddard's solvent, to prevent staining. If a solvent is not used and the metal stains, the discoloration can be removed by immersing for 20 to 30 min. in a cold bath of 10% sodium cyanide solution. Extreme caution should be observed in handling sodium cyanide, because this solution is a deadly poison.

Tarnish, resulting from humid or sulfur-bearing atmospheres, can be removed from oil-free parts by a short immersion in the above sodium cyanide solution or dilute (5 to 10% by volume) sulfuric or hydrochloric acid solutions at room temperature. Pieces should be thoroughly rinsed in water following either cyanide or acid dips.

Oil or grease are rapidly removed by vaporized solvents such as trichlorethylene. For degreasing, parts are placed in a container where solvent vapors can condense on it. Condensate washes away the oily coating and leaves the piece clean and dry.

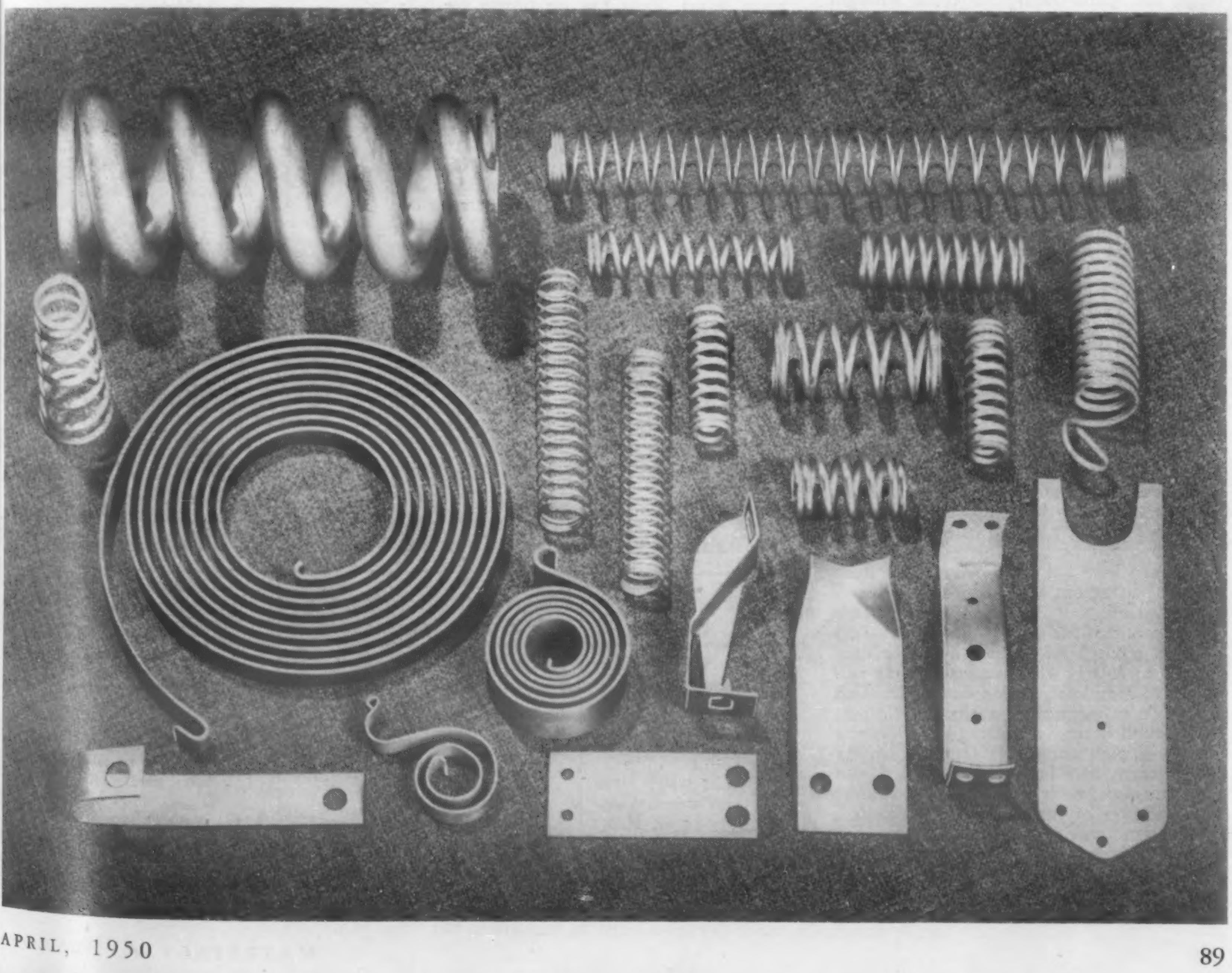
Alkaline cleaning solutions are also satisfactory for the removal of oil, grease and dirt. Various combinations of sodium carbonate, trisodium phosphate, sodium metasilicate and similar materials are used. Operating temperatures and concentrations depend upon the desired surface condition and the oil or dirt to be removed.

There are available several proprietary electrolytic cleaning methods which give good results in removing dirt and scale, leaving a bright and clean surface. Good results have been obtained in handling cast-



Typical beryllium copper mechanical parts blanked, spun and machined from strip and rod.

Miscellaneous beryllium copper, flat, compression, extension, torsion and power springs.



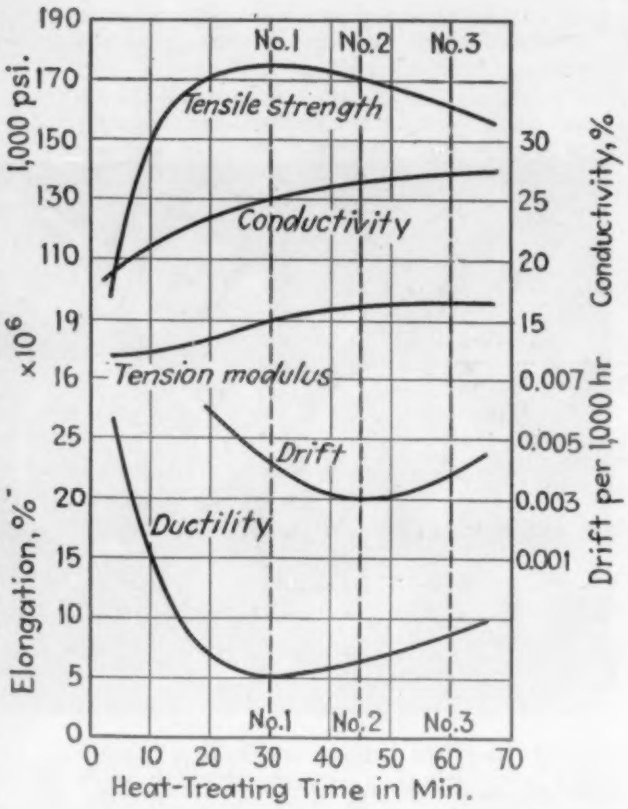


Fig. 14—Property changes of annealed beryllium copper (25 Alloy) strip during age hardening at 660 F. (Williams)

ings and parts fabricated from wrought products.

Where it is desirable to protect the surface finish obtained through cleaning, either a lacquer or plastics coating can be applied by brushing, spraying or dipping. Parts should be coated immediately after cleaning to prevent discoloration.

Pickling

An oxide film forms on beryllium copper when heated in an uncontrolled atmosphere into either the hardening or annealing range. When necessary for appearance, soldering, brazing, welding, plating, pressworking or similar operations, this scale can be easily removed by pickling.

To insure effective cleaning, it is essential that oil, grease and other lubricants be completely removed prior to pickling. When solution-annealing or aging precedes pickling, parts should be carefully degreased before heating and some care should be exercised to prevent contamination with oil or grease between heat treating and cleaning. In addition, pickling baths should not contain scraps or stray pieces of iron or steel, otherwise red stains may result from copper plating out and onto parts.

For pickling, a 20 to 30% by volume solution of sulfuric acid (concentrated, 1.83 specific gravity) and water should be used at 160 to 180 F, with immersion time sufficient to completely loosen dark scale. This operation is followed by a nitric acid dip to remove all traces of black scale (cupric oxide) as well as any red (cuprous oxide) stains which may be present. Parts should be immersed briefly in a 30% by volume cold solution of nitric acid (concentrated, 1.40 specific gravity) and water. Immersion time, which is limited to prevent etching the base metal, is best determined by trial.

Acid stains may result unless parts are carefully cleansed of all acid after pickling or bright dipping. Thorough washing in cold water followed by a hot rinse are necessary to remove all traces of acid before drying by air blast, sawdust or other available means. An acid-neutralizing dip in a soap solution is sometimes desirable between the final cold and hot water rinses. In addition to the final washing, parts must be thoroughly rinsed in cold water between successive acid treatments.

Plating

Beryllium copper components can be plated for appearance, added protection, die lubrication and electrical properties with the following metals: cadmium, zinc, tin, copper, chromium, nickel, silver, rhodium and gold. Some caution should be observed, however, in coating critical elastic elements (springs, diaphragms, etc.), since plating introduces excessive anelastic behavior as measured by drift and hysteresis. On the other hand, plating baths do not cause a hydrogen embrittlement in beryllium copper, so that endurance will not be adversely influenced.

Where service requirements demand a white surface, either nickel or tin plating can be applied. Although tin remains white longer in mildly corrosive atmospheres and provides sacrificial protection under severely adverse conditions, the final selection between these metals will depend upon economy and the corrodants present.

A tin base is of advantage in soft soldering, since it permits the use of noncorrosive rosin fluxes. Parts can be tinned by hot-dipping in conjunction with a chloride flux to give coatings roughly 0.0008 in. thick, while electroplating can be employed to deposit coatings meeting the minimum thickness requirement for soldering of 0.0003 to 0.0005 in.

Tin, zinc and cadmium coatings can be used to compensate for differences in electrochemical potential at bimetallic junctions. In addition, cadmium plate of the order of 0.0001 to 0.0003 in. thick is frequently used as a die lubricant in pressworking to enhance punch and die life. For resistance to corrosion from phenolic or vinyl plastics or rubber, beryllium copper molds are usually given a hard chromium plate, 0.003 to 0.006 in. thick.

Where special electrical characteristics, including high-frequency conductance and low contact resistance are necessary, it might be desirable to plate with such noble metals as silver, gold or rhodium. Of these metals, silver is the most widely used; however, gold can be employed for low resistance at very light pressures while rhodium offers unusual combinations of corrosion and wear resistance, hardness, reflectivity, and low and stable contact resistance.

Since the surface condition of material entering the plating bath exerts the greatest influence on the final result, it is essential that parts be absolutely clean and free from oxide, oil, grease and dirt. Where chromic acid or dichromate pickling solutions may have proceeded plating, it is necessary to remove the thin oxide film formed thereon by a cold 30% nitric acid bath prior to plating in order to insure good adherence of the plate. Recommended procedures for alkaline cleaning, vapor degreasing and pickling are given above.

Coloring

To meet certain service requirements, it may occasionally be necessary to color beryllium copper components. Table XVI lists suggested coloring treatments, while proprietary processes are also available. In coloring, immersion in a given solution may produce one or more colors, so that the part should be held in the bath until the desired tone is obtained. In all cases, parts should be thoroughly cleaned prior to coloring, while a polished surface is necessary to obtain best results. This surface requirement frequently makes it difficult to handle castings.

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Table XVI—Typical Coloring Solutions for Beryllium Copper

Black	Steel Black	Reddish Bronze Brown Blue-Black
1. Chemically clean 2. Immerse in water solution of potassium sulfide for 5-10 sec. at 100 F 3. Cold water rinse 4. Hot water rinse 5. Dry by air blast 6. Lacquer	1. Chemically clean 2. Immerse in solution at 180 F until uniform color is obtained: 4 oz. arsenious oxide (white arsenic) 8 oz. hydrochloric acid (sp. gr. 1.16) 3. Scratch brush while wet 4. Cold water rinse 5. Hot water rinse 6. Dry by air blast 7. Lacquer	1. Chemically clean 2. Immerse in solution at 170 F until desired tone is reached: 2 oz. potassium sulfuret (liver of sulfur) 3 oz. caustic soda 1 gal. water 3. Cold water rinse 4. Hot water rinse 5. Dry by air blast 6. Scratch brush 7. Lacquer

Materials & Methods

Materials Engineering File Facts

NUMBER 190
April, 1950

MATERIALS DATA SHEET

Wrought Phosphor Bronzes

Typical Properties

TYPE	Phosphor Bronze, 5% (Grade A)	Phosphor Bronze, 8% (Grade C)	Phosphor Bronze, 10% (Grade D)	Phosphor Bronze, 1.25% (Grade E)
COMPOSITION, %	Cu, 94.0 min. Sn, 3.5-5.8 P, 0.03-0.35	Cu, 90.5 min. Sn, 7.0-9.0 P, 0.03-0.35	Cu, 88.5 min. Sn, 9.0-11.0 P, 0.03-0.25	Cu, 98.5 min. Sn, 1.0-1.5 P, trace
PHYSICAL PROPERTIES				
Density, Lb./Cu. In.	0.320	0.318	0.317	0.321
Melting Range, F	1750-1920	1620-1880	1550-1830	1900-1970
Thermal Cond., Btu./Hr./Sq. Ft./Ft./F, @ 68 F	47	36	29	120
Coeff. of Exp. per F (68-572 F):	9.9×10^{-6}	10.1×10^{-6}	10.2×10^{-6}	9.9×10^{-6}
Spec. Ht., Btu./Lb./F, @ 68 F:	0.09	0.09	0.09	0.09
Elect. Res., Microhm-Cm. @ 68 F (Annealed):	9.6	13	16	3.6
MECHANICAL PROPERTIES				
Mod. of Elasticity in Tension, Psi.	16.0×10^{6}	16.0×10^{6}	16.0×10^{6}	17.0×10^{6}
Tensile Str., 1000 Psi. (Flat Products, Wire):				
Annealed	47, 50	55, 60	66, 66	40, —
Half-Hard	68, 85	76, 105	83, 118	55, —
Hard	81, 110	93, 130	100, 147	65, 76
Spring	100, 140	112, —	122, —	75, —
Extra Spring	107, —	120, —	128, —	—, —
Yield Str., 1000 Psi.[1]:				
Annealed	19	24	28	14
Half-Hard	55	55	—	—
Hard	75	72	—	50
Elongation in 2 In., %:				
Annealed	64	70	68	48
Half-Hard	28	32	32	16
Hard	10	10	13	8
Spring	4	3	4	4
Extra-Spring	3	2	3	—
Hardness, Rockwell B:				
Annealed	26	50	55	—
Half-Hard	78	84	92	64
Hard	87	93	97	75
Spring	95	98	101	79
Extra-Spring	97	100	103	—
FABRICATING PROPERTIES				
Capacity for Being Cold Worked	Excellent	Good	Good	Excellent
Capacity for Being Hot Worked	Poor	Poor	Poor	Good
Hot Working Temp., F	—	—	—	1450-1600
Annealing Temp., F	900-1250	900-1250	900-1250	900-1200
Machinability Index (Free Cutting Brass = 100)	20	20	20	20
Joining Characteristics:				
Soft Soldering	Excellent	Excellent	Excellent	Excellent
Silver Alloy Brazing	Good	Good	Good	Excellent
Oxyacetylene Welding	Good	Good	Good	Good
Carbon Arc Welding	Good	Good	Good	Good
Resistance Welding	Good	Excellent	Excellent	Fair
Common Fabrication Processes	Blanking, drawing, forming and bending, heading and upsetting, roll threading and knurling, shearing, stamping.	Blanking, drawing, forming and bending, shearing, stamping.	Blanking, forming and bending, shearing.	Blanking, forming and bending, heading and upsetting, shearing, squeezing and swaging.
CORROSION RESISTANCE	Generally good resistance to atmosphere, water and salt water, salt solutions. Some resistance to alkaline solutions and inorganic acids. Poor resistance to organic acids, cyanides and ferric and ammonium compounds.			
AVAILABLE FORMS	Rolled strip, rolled flat wire, rod, wire, tube.	Rolled strip, rod, wire.		Rolled strip, wire.
USES	Bridge bearing plates. Chemical hardware, perforated sheets, textile machinery, welding rods, beater bars, bellows, clutch disks, cotter pins, diaphragms, fuse clips, fasteners, lock washers, sleeve bushings, springs, switch parts, truss wire, wire brushes.		Heavy bars and plates for severe compression, good wear and corrosion resistance. Bridge and expansion plates and fittings. Articles requiring extra spring qualities, particularly in fatigue.	Electrical contacts, flexible hose, pole-line hardware.

[1] *Yield strength at 0.5% extension under load.*

Prepared with the assistance of the Copper & Brass Research Assn.

Materials Engineering File Facts

NUMBER 191
April, 1950

MATERIALS: Thermosetting Plastics

Long-Time Strength of Thermosetting Plastics

Many of the present applications of plastics involve sustained stress and continuing deformation. The use of plastics as light-duty structural members has intensified the need for authoritative creep data. It is the purpose of this table, therefore, to summarize briefly the most recently available creep data on the phenolic thermosetting plastics. This is done by listing for various types of thermosetting plastics the stress to which they can be subjected for several years without showing significant creep.

Although the results obtained by several investigators show general agreement in many cases, the limited number of investigations made and the varied materials and conditions employed make it necessary to consider *these values only as approximations.* Generally, these estimates are believed to be on the conservative side.

Predicted Long-Time Strength of Phenolic Thermosetting Plastics

	75 F (50% Relative Humidity)						180 F				
	Short-Time Ult. Str., Psi.	Mod. of Elasticity in Tension, Psi. x 10^6	Estimated Long-Time Ultimate Strength, Psi.		Estimated Long-Time Ult. Str., % of Short-Time Ult. Str.		Mod. of Elasticity in Tension, Psi. x 10^6	Estimated Long-Time Ultimate Strength, Psi.		Estimated Long-Time Ult. Str., % of Short-Time Ult. Str. at 75 F	
Material			Unnotched	Notched	Unnotched	Notched		Unnotched	Notched	Unnotched	Notched
Woodflour-Filled	6100	1.28	2000-2800	1000-1400	39	20	1.30	1200-1400	600-700	21	11
Asbestos-Filled	4400	2.47	1500-3200	900-1900	53	32	2.30	1300-1400	700-800	31	17
Chopped Kraft Paper-Filled	7700	1.42	2700	2100	35	27	1.39	1200	900	16	12
Macerated Fabric-Filled	5600	1.49	2000	2000	36	36	1.45	1200	1200	21	21
Cotton Flock-Filled	7500	1.40	2700	1900	36	25	1.48	1200	900	16	12
Mica-Filled	5400	4.50	1600-2400	1200-1800	37	28	—	1200-1500	900-1200	25	21
Cord-Filled	6000	—	2400-3000	—	45	—	—	900-1200	—	19	—
Rag-Filled	6100	—	2400-3000	—	44	—	—	1200-1400	—	21	—
Resin Compound	8900	—	1600-2400	—	22	—	—	<100	—	<1	—

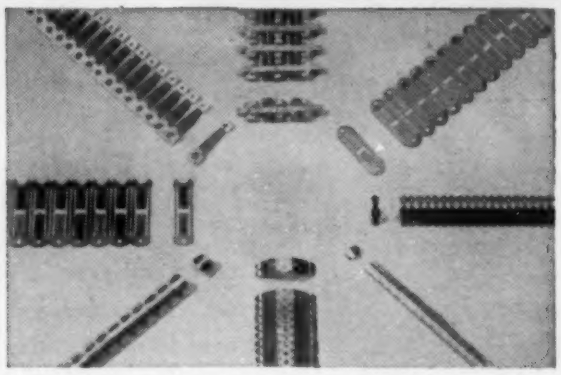
The data in this table are adapted from published research by C. E. Staff, H. M. Quackenbos, Jr., J. M. Hill, D. Telfair, T. S. Carswell, H. K. Nason and W. J. Gailus.

I-S SPRINGS of beryllium copper *can help you*

IMPROVE YOUR PRODUCT'S QUALITY, REDUCE YOUR COST, INCREASE YOUR PRODUCTION

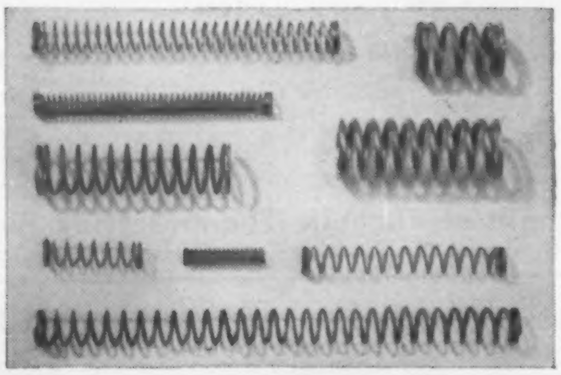
Instrument Specialties Company specializes in the design and custom manufacture of age-hardened alloy springs. With our specially developed processes and machines, our engineers are able to realize the fullest performance potential from the superior spring materials around which I-S service to designers and manufacturers has been developed.

FOR HIGH PRODUCTION



STRIP SPRINGS

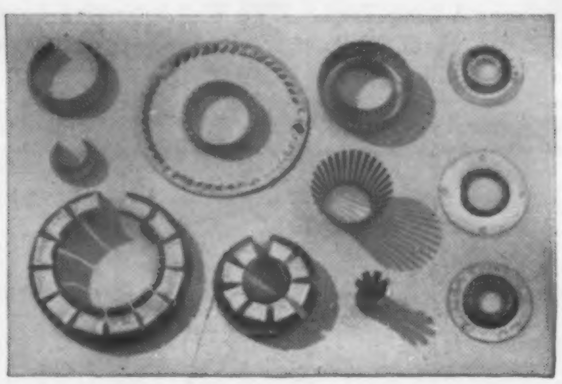
Fabricated from beryllium copper.
Easily handled, readily broken apart by hand or used in automatic or semi-automatic assembling devices and contact riveting machines.
Individual pieces may be broken off without trace of burr.
Eliminate sorting, untangling and handling of loose pieces.
Springs may be produced in strips to various shapes; formed angles may be held within plus or minus one degree.
Heat treated in multiple fixtures to insure uniformity, close tolerances and elimination of variations in spring-back.



COIL SPRINGS

Made from laboratory tested beryllium copper wire.
Special coil and heat treating equipment insures 100% uniformity.
Guaranteed rigid tolerances held on diameter and load tests at specified deflection.
These factors combine to assure increased service life through higher endurance strength—make products perform more consistently by eliminating drift, set or fatigue. Furthermore, they eliminate expensive hand adjustment and reduce inspection costs of finished product.

FOR LOW ACTIVITY

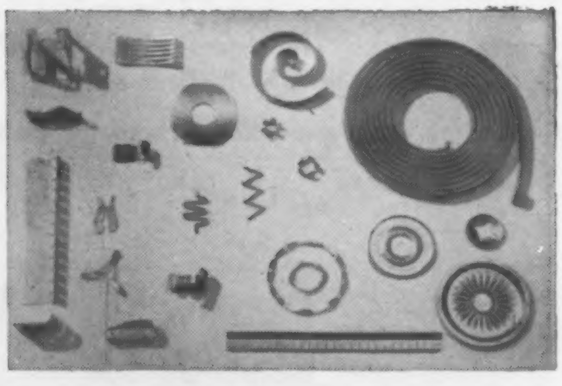


HIGH FREQUENCY SPECIALTIES

We are equipped to supply standard mating parts for use with 2C-39, 2C-40, 2C-43 and 3C-37 tubes, or custom made parts in related fields.

Grounding strips and contact fingers can be supplied in standard or special contours.

"Flea" contacts for subminiature tubes.



SHORT-RUN SERVICE

For those who need quick delivery of parts in pilot quantities or require a low-cost proving ground for spring designs. I-S methods eliminate expensive tooling. Laboratory controlled, precision produced—yet at lower cost than is possible with permanent, high-activity tools.

We are equipped to handle conventional stampings in short runs or in high production.

"MICRO-PROCESSED" I-S BERYLLIUM COPPER SPRINGS

A COMPLETE ENGINEERING AND SAMPLE SERVICE

When your product is in the design stage, let us show you how I-S springs of beryllium copper may be designed to fit your needs. Ample stock, flexible facilities, short set-up time speed production of sample lots and trial orders.

INSTRUMENT SPECIALTIES CO., INC.

224 Bergen Boulevard Little Falls, New Jersey

Telephone: Little Falls 4-0280

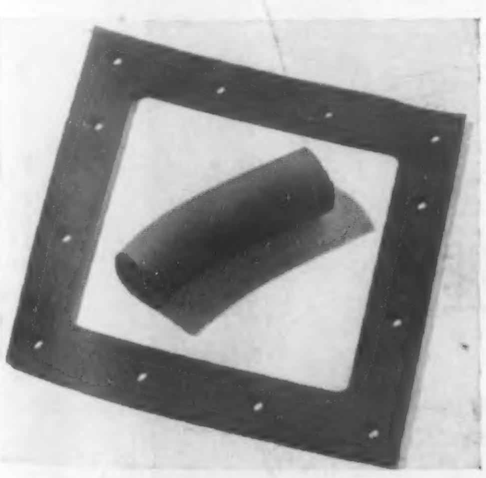
New Materials and Equipment

Materials

Silicone Rubber Sponge

An improved Cohrlastic silicone rubber sponge, claimed to be suitable as a vibration dampener for extreme temperatures, is now available from *Connecticut Hard Rubber Co.*, 407 East St., New Haven 9, Conn.

This company has had a silicone rubber sponge on the market for two years, but the new sponge has been made from recently developed silicone compounds. The cell size of this new sponge is claimed to be more uniform than in earlier constructions and the material has improved tensile strength, elongation, tear strength and abrasion resistance. It has a density of 25 to 35 cu. in. per lb. and resists temperatures from -100 to 500 F.



The new Cohrlastic sponge has been made from recently developed silicone rubber compounds.

The material is available from stock in sheets 1/16-, ⅛- and ¼-in. thick which can be cut for fairing strips, seals, gasketing, etc., and is also available in special extrusions and molded shapes.

Modified Aluminum Alloy

A new aluminum alloy, quite similar to 61S but with improved formability, has been developed recently by *Aluminum Co. of America*, Oliver Building, Pittsburgh 19, Pa. Called 62S, the alloy owes its improved working properties to a somewhat reduced chromium content and generally finer grain sizes.

Principal advantages of the new alloy are claimed to be as follows:

1. Better appearance caused by finer grain size.
2. More uniform "spring-back" during forming in the T-6 temper condition (solution treated and aged).
3. Lower yield strength and slightly better workability in annealed condition.

Mechanical properties of 62S are believed to be generally the same as those of 61S. Thus, typical values in the neighborhood of 45,000 psi. tensile strength, 40,000 psi. yield strength, 17% elongation (rod), and 95 Brinell hardness can be expected in the T-6 temper. Annealed, these typical properties run 18,000 psi. tensile strength, 8000 psi. yield strength, 30% elongation (rod), and 30 Brinell hardness.

Applications of 62S are expected to be about the same as those of 61S, which is widely used in the marine field.

CONTENTS

Parts & Forms

Extruded Plastic Pipe

A semi-rigid plastic pipe, designated as Carlon T, has been developed by *Carter Products Corp.*, 10235 Meech Ave., Cleveland 5, Ohio, to supplement its standard line of flexible pipe. This extremely lightweight pipe is claimed to eliminate many pipe installation problems as well as the need for materials handling equipment.

The plastic construction of T pipe eliminates problems of rot, rust and electrolytic and galvanic corrosion. The durable pipe

New Materials and Equipment
(CONTINUED)

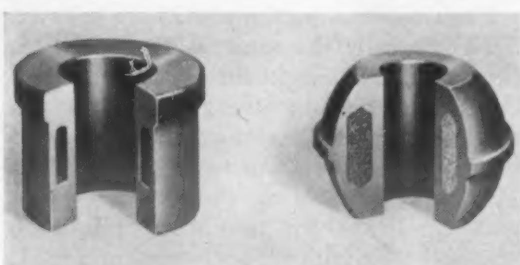
is said to have a projected service life more than double that of ordinary pipe, even under severest operating conditions. Its semi-rigid characteristics make it suitable for suction lines and transmitting industrial sewage, as well as for exhaust systems handling highly corrosive gases.

Furnished in random 20-ft. lengths, Carlon T pipe sections are connected by means of plastic sleeves, which are first treated with a special cement and then slipped over the ends of the sections to be joined. Threaded plastic sleeves can be furnished to permit connection of Carlon T to established metal pipe installations equipped with standard fittings.

Sintered Metal Bearing

An oil-impregnated sintered metal bearing, known as the Haller Oil Well Bearing, has been developed by *Michigan Powdered Metal Products Co., Inc.*, Northville, Mich.

The oil, which is absorbed by the sintered metal, also fills a cavity in the center of the bearing wall, resulting in a greater oil content than is possible in conventional bearings. This increased lubricating quality is said to practically eliminate "freezing" under even extremely adverse operating conditions.



Oil retention in these Haller Oil Well Bearings is increased by a central cavity, sometimes filled with sponge iron (as on the right).

Coatings & Finishes

Dust Repellent

A liquid called Logo Stat, claimed to provide an inexpensive, easily applied treatment for polystyrene to prevent attraction of dust, is being manufactured by *Bee Chemical Co.*, 13799 South Ave. "O", Chicago 33, Ill. The material is applied by dipping immediately after molding to prevent dust accumulation during handling. It is said to be quick-drying, insoluble in water following application, and unnoticeable on the plastic.

Electroplating Aluminum

A complete electroplating process claimed to be suitable for all regularly used alloys of aluminum has been developed by *MacDermid, Inc.*, Huntington Ave., Waterbury, Conn.

The Alumetex Process consists of an alkaline non-etch type cleaner, two acid etches, and an immersion coating prior to electroplating the aluminum with a copper flash. Any type of electrodeposit can be used on the copper flash.

Advantages claimed for the process are: (1) good corrosion resistance and adhesion obtained by simple immersion treatments; (2) complete elimination of blisters, pits and dull deposits; and (3) sand castings, die castings and wrought aluminum can be processed through the same cycle.

Nonferrous Metal Finishes

Three new products, including a chromate-type, corrosion resistant finish for aluminum, have been announced recently by *Allied Research Products, Inc.*, Baltimore 2, Md. The other products are a powder form of an Iridite coating for the protection of zinc and cadmium, and a new type of organic brightener for zinc plating solutions.

The aluminum finish, known as Iridite Alcote, is said to resist salt spray for as long as 1000 hr. on wrought stock and 250 hr. on castings, depending upon the alloy and the treating time. In addition, the coating is claimed to be highly resistant to abrasion; treated parts can be buffed and mechanically handled or formed without materially affecting the finish. Iridite Alcote serves as a good paint base and also seems to aid materially in shielded-arc welding, but current tests indicate that there may be limitations on its use on parts to be spot welded.

Like the Iridite finishes for zinc and cadmium, Iridite Alcote is applied to parts by a simple, non-electrolytic dip with the solution operating at room temperature. No fumes are given off during processing and, consequently, no exhaust systems are required. The coating ranges in color from clear to light bronze, and can be obtained from as short an immersion as 10 sec. Recommended immersion time for greatest color intensity and corrosion resistance is 2 min.

The new zinc plate brightener compound is called ARP No. 3 and will be supplied in liquid form for use in any type of zinc plating bath. It is claimed to produce better results at lower cost than established materials now on the market.

Heating

Pilot Tunnel Kiln

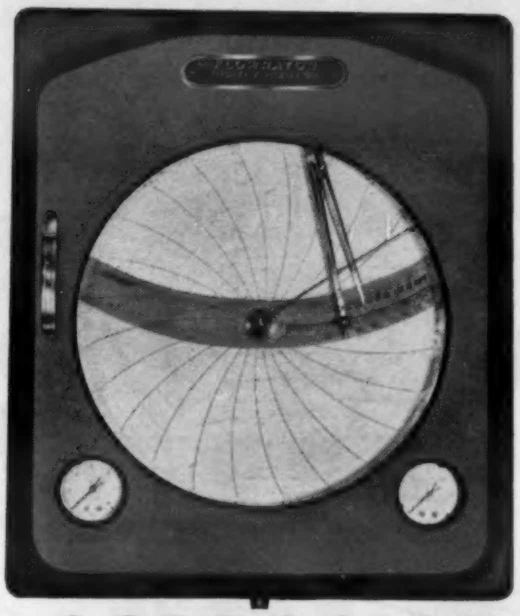
A small tunnel kiln for speeding up production test runs is being manufactured by *Harper Electric Furnace Corp.*, 1461 Buffalo Ave., Niagara Falls, N. Y.

The kiln has been designed to permit duplication of most firing schedules. It is being used in test firing of ceramic powders, steatite, electrical porcelain, insulators, electronic components and other ceramic products.

This Harper kiln allows firing schedules to be established at a first low cost of equipment.

Heating for Welding

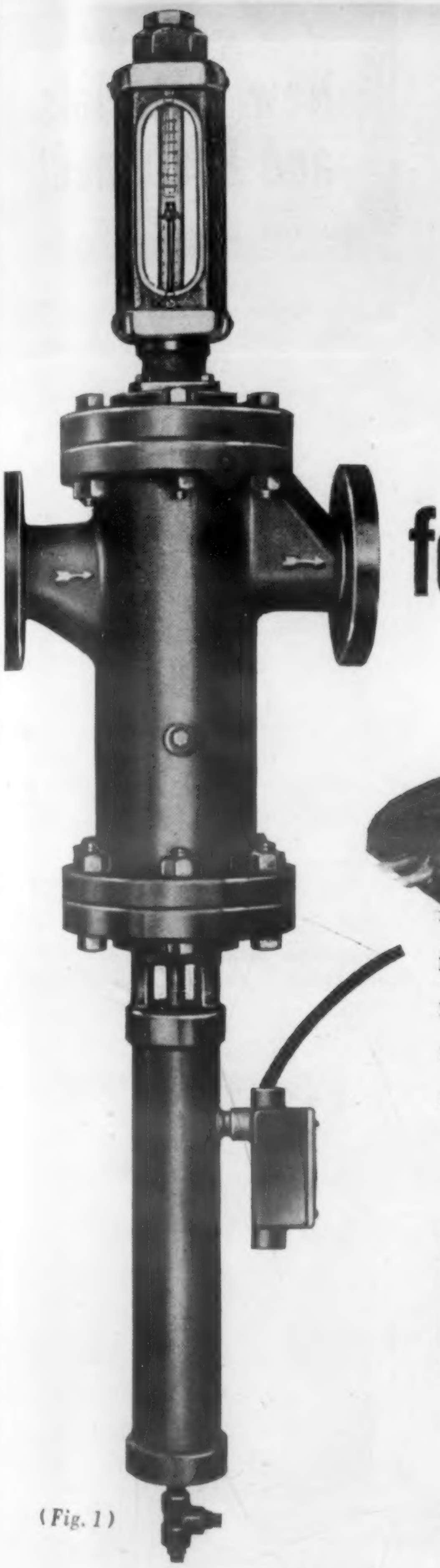
A two-unit combination for pre-heating before welding and stress relieving after welding has been announced by *Electric Arc, Inc.*, 152-162 Jelliff Ave., Newark, N. J. The equipment is known as the 40-Kva. Model RTA Regulating Unit and



"MEEHANITE® METER FITTINGS ACCEPTABLE for CORROSION RESISTANCE"

Meehanite FLOWRATOR flow meters and VALVRATOR diaphragm motor valves for continuous proportioning strip pickler at a tin plate mill.

(*Fig. 2*)



(*Fig. 1*)

FISCHER & PORTER COMPANY, Hatboro, Pa., make the headlined statement as a result of experiment, research and experience in the field. A specific instance is found in the Flowrator Meters (Figure 1) applied to achieve accurate pickling acid measurement (Figure 2). Close measurement control is a recent development and is fundamentally dependent upon the corrosion resistance of the component parts of the instrument.

In this application the flowmeter measures 60° to 66° Baume sulphuric acid.

Considerable research has been devoted to the development of a number of Meehanite metals to meet specific corrosive problems. However, in all applications of Meehanite castings the problem is attacked from the standpoint of the achievement of the proper metallurgical constitution of the material to give maximum service, whether it be resistance to wear, heat, corrosion or destructive stresses.

If you are faced with problems involving castings which must provide the maximum combination of properties for your needs, turn to your Meehanite foundry for the answer. Ask for the Handbook of Meehanite Metals.

Take Your Casting Problems To A MEEHANITE Foundry!

American Brake Shoe Co. — Mahwah, New Jersey
The American Laundry Machinery Co. — Rochester, New York
Atlas Foundry Co. — Detroit, Michigan
Banner Iron Works — St. Louis, Missouri
Barnett Foundry & Machine Co. — Irvington, New Jersey
E. W. Bliss Co. — Hastings, Mich. and Toledo, O.
Builders Iron Foundry Inc. — Providence, Rhode Island
H. W. Butterworth & Sons Co. — Bethayres, Pennsylvania
Continental Gin Co. — Birmingham, Alabama
The Cooper-Bessemer Corp. — Mt. Vernon, Ohio and Grove City, Pa.
Crawford & Doherty Foundry Co. — Portland, Oregon
Farrel-Birmingham Co., Inc. — Ansonia, Connecticut
Florence Pipe Foundry & Machine Co. — Florence, New Jersey
Fulton Foundry & Machine Co., Inc. — Cleveland, Ohio
General Foundry & Manufacturing Co. — Flint, Michigan
Greenlee Foundry Co. — Chicago, Illinois
The Hamilton Foundry & Machine Co. — Hamilton, Ohio
Johnstone Foundries, Inc. — Grove City, Pennsylvania
Kanawha Manufacturing Co. — Charleston, West Virginia
Koehring Co. — Milwaukee, Wisconsin
Lincoln Foundry Corp. — Los Angeles, California
E. Long Ltd. — Orillia, Ontario
Otis Elevator Co., Ltd. — Hamilton, Ontario
The Henry Perkins Co. — Bridgewater, Massachusetts
Pohlman Foundry Co., Inc. — Buffalo, New York
The Prescott Co. — Menominee, Michigan
Rosedale Foundry & Machine Co. — Pittsburgh, Pennsylvania
Ross-Meehan Foundries — Chattanooga, Tennessee
Shenango-Penn Mold Co. — Dover, Ohio
Sonith Industries, Inc. — Indianapolis, Ind.
Standard Foundry Co. — Worcester, Massachusetts
The Stearns-Roger Manufacturing Co. — Denver, Colorado
Traylor Engineering & Mfg. Co. — Allentown, Pennsylvania
Valley Iron Works, Inc. — St. Paul, Minnesota
Vulcan Foundry Co. — Oakland, California
Warren Foundry & Pipe Corporation — Phillipsburg, New Jersey

"This advertisement sponsored by foundries listed above."

MEEHANITE®

PERSHING SQUARE BUILDING • NEW ROCHELLE, N. Y.

New Materials and Equipment

40-Kva. Model AC3 Low Frequency Induction Heating Unit by the Smith-Dolan System.

This combination is designed for use in

Above is the Model AC 3 induction heating unit; below is the Model RTA regulating unit.

limited space where the extreme flexibility of this company's smallest induction heater (10-Kva. Model VP) is not needed. With these models, more equipment can be added as required.

Welding and Joining

Welding Torches

Two new welding torches with cutting attachments have been introduced by K-G

New Materials and Equipment

Welding & Cutting Co., Inc., 515 W. 29 St., New York City.

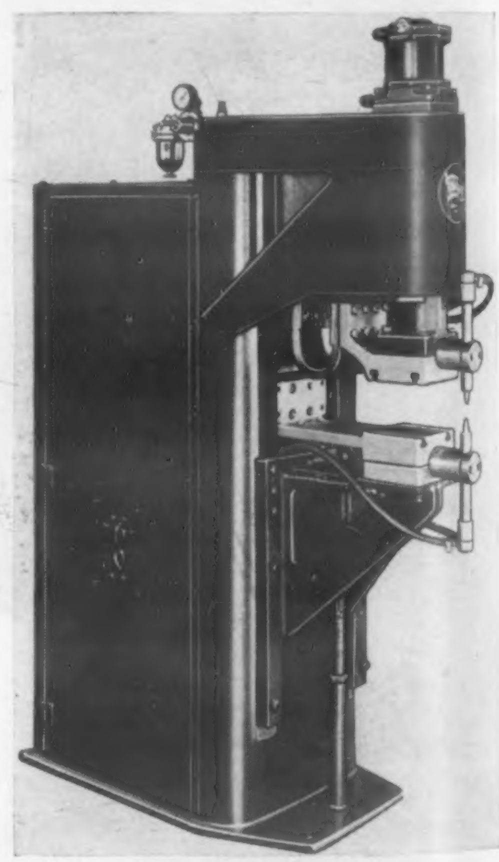
The smaller E50 Torch has a welding range up to tip size 40 and cutting range up to tip size 45. The larger K50 torch has a welding range up to tip size 20 and cutting range up to tip size 40.

Low Hydrogen Electrodes

A complete line of low hydrogen electrodes is now being produced by the Welding Div. of *Harnischfeger Corp.*, 4400 W. National Ave., Milwaukee 14, Wis. The series comprises 14 different types, covering all welding applications where deposits low in hydrogen are desirable to eliminate under-bead cracking.

Projection Welders

Banner Manufacturing Co., 4934 N. 29 St., Milwaukee, Wis., has announced a new



The new Banner projection welders range in size from 50 to 150 Kva.

line of press type, air-operated projection and spot welders. They range in size from 50 to 150 Kva. and are said to incorporate many innovations in design and construction over former equipment.

Ample capacity for a wide range of

It pays to use your custom molder's know-how

you may find you need fewer parts!

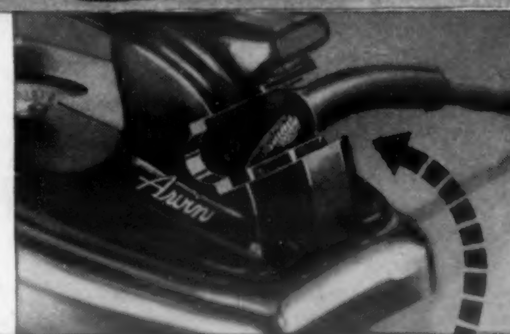
No. 16 in a series on Plastics Skill at Work...

PROJECT
Handle for Arvin DeLuxe Electric Iron

CUSTOMER
Noblitt-Sparks Industries, Inc., Columbus, Indiana

MOLDER
Plastics Research Products Co., Urbana, Ohio

MATERIAL
Durez general-purpose phenolic plastic



CORD-RETAINER INSERT is quickly reversible to make same iron "right-" or "left-handed." The 1-piece main body of handle, originally planned as a 2-piece unit, is molded in same mold as the insert. Customer saved almost 50% on mold costs formerly estimated.

● Suppose you had designed an iron to gladden any ironer's heart, only to find that the plastic handle would have to be made in two halves to retain all its selling points and hence would cost too much.

What to do? Using successful past experience as a guide, Noblitt-Sparks engineers conferred with their custom molders.

Drawing on a solid background of plastics and molding techniques, these molders helped to work out a new one-piece Durez handle with the desired heart-shaped indicator window, thermostat knob recess, undercut engraving, and a separate cord retainer that converts the iron for right- or left-hand use in an instant. This new handle eliminated the costly operation of assembling two component halves with screws and inserts. The high natural finish of the Durez phenolic makes buffing unnecessary. Flash is removed by an undercutting profile fixture, thus providing a smooth, comfortable, and decorative solution to an otherwise costly hand cleaning problem.

Not every manufacturer can use his molder's know-how to reduce the number of molded parts *and their cost* by as much as a third, as this one did. Yet good custom molders can supply good ideas as well as good moldings.

Like Plastics Research Products, your molder knows how to use the excellent properties of Durez plastics to your best advantage. Call freely on him — and on us.

A hit with plastics users everywhere is the handy "Durez Check-Chart." Write for yours. Durez Plastics & Chemicals, Inc., 144 Walck Rd., N. Tonawanda, N. Y.

DUREZ

PHENOLIC RESINS: MOLDING COMPOUNDS · INDUSTRIAL RESINS · PROTECTIVE COATING RESINS

PHENOLIC PLASTICS THAT FIT THE JOB

New Materials and Equipment

metals is assured by a heavy-duty transformer, equipped with an 8-stage series parallel heat selector switch. When the machines are equipped for spot welding, 2¾-in. dia. arms and 1¼-in. dia. ejector type holders are provided.

Soldering Unit

A new soldering unit for all types of operations, including silver soldering and brazing, has been announced by *Wasserlein Manufacturing Co., Inc.*, 7400 Third Ave., No., St. Petersburg 6, Fla. The Wassco Glo-Melt operates on the conduction principle and has a 24-heat selector for handling lightest up to heaviest work.

The Wassco Glo-Melt Unit is claimed to be suitable for rapid, precision soldering.

The 25-lb. unit has a capacity equal to a 450-watt heavy electric iron. Soldering is done with a 5-oz. handpiece.

Cast Iron Electrode

An electrode recommended for general welding of cast iron, especially where free machinability and color match are required, has been introduced by *All-State Welding Alloys Co., Inc.*, 273 Ferris Ave., White Plains, N. Y. It is designated as All-State No. 8 New Machinable Cast Iron Electrode.

The electrode has a core that is more than 99% nickel and is 15 in. long instead of the usual 14 in., proportionately reducing stub losses. It is designed for a.c. or d.c. straight or reverse polarity and amperages ranging from 40 to 180, depending on diameter. It is claimed to produce welds having tensile strengths from 30,000 to 50,000 psi.

New Materials and Equipment

Forming

Pneumatic Drop Stamp

Chambersburg Engineering Co., Chambersburg, Pa., has announced the addition of a new Cecostamp, Model L, to its line of air-operated drop stamps. The new machine is said to be 10% more powerful than preceding Cecostamps.

Among several important safety features is the location of the control mechanisms in such a position that the operator is free of moving parts.

Cecostamp Model L has been added to the Chambersburg Engineering line.

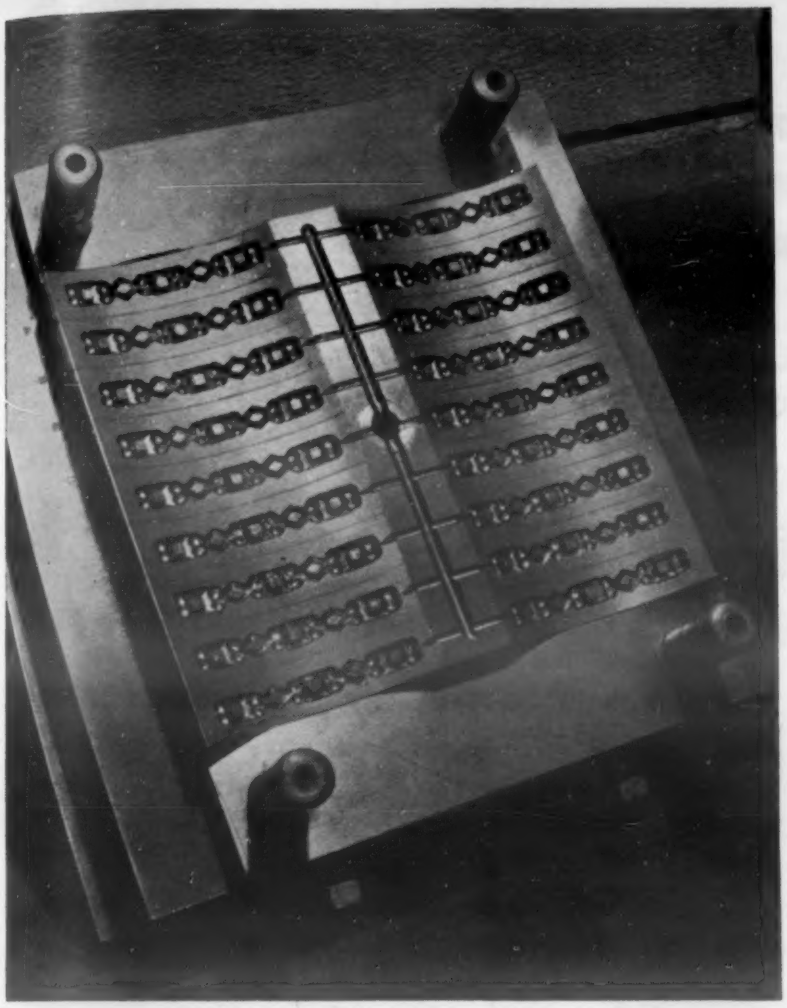
Controlled Metal Forming

The Marform metal forming units developed by *Glenn L. Martin Co.* are being made available to industry generally by *Hydropress, Inc.*, 570 Lexington Ave., New York City. These units have enabled Martin engineers to cut costs of formed sheet metal parts by as much as 50%. Specific advantages of the process have been described previously in MATERIALS & METHODS (Oct. 1949, p. 143).

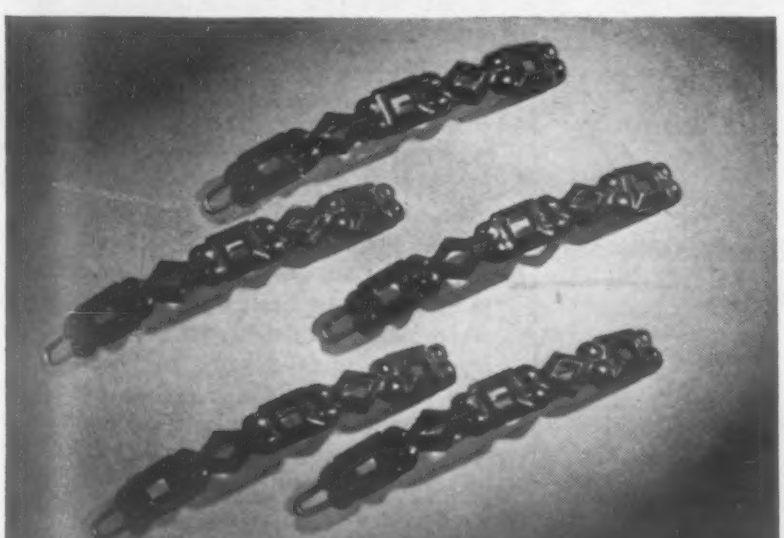
The process depends upon precision con-

DURAMOLD A

Air-Hardening Hobbing Steel for Mold Cavities



Hobbed from Duramold A in one push, this mold is a fine example of the intricate detail which can be attained in hobbing. The square and diamond-shaped "core pins" were raised up in the mold by the pressure of the master hob. Movement in heat-treatment was held to a minimum.



The highly polished surfaces of the mold made possible a high-quality finish on these injection-molded plastic barrettes. Mold made by Banner Mold & Die Co., Inc., Leominster, Mass. Plastic molding by E. B. Kingman Co., Leominster, Mass.

Duramold A has outstanding advantages for mold cavities used in the plastics industry. It's easy to hob . . . and its 5 pct chromium content provides high wear-resistance and core strength. Distortion in hardening is minimized by its air-hardening characteristics.

Duramold A has the balanced alloy content that meets today's requirements for a hobbing steel with high mechanical properties. Here are the facts:

High Wear-Resistance. Duramold A is suitable for long runs because of its alloy content and high surface-hardness after carburizing (Rockwell C—61 to 63).

Holds Close Dimensions. Air-hardening greatly reduces distortion in hardening, making Duramold A suitable for intricate cavities, thin sections.

Easy to Hob. It anneals to less than 109 Brinell and hobs deeper than the nickel-chromium steels. It does not work-harden rapidly.

Takes High Polish. Duramold A is scrupulously inspected to assure a clean, sound structure. The 5 pct chromium content provides improved corrosion-resistance, as compared with ordinary hobbing steels.

For High Temperatures and Pressures. It is suitable for operating temperatures up to 650 F. Its high core strength permits high pressures.

High Surface Hardness. An air-cool, following carburizing at 1700 F and a 300 to 400 F temper, results in a surface hardness of Rockwell C—61 to 63. Core hardnesses are in the range of Rockwell C—30.

For Machined Cavities. When Duramold A is used for a machined cavity, it is annealed at 1600 F to obtain a Brinell hardness of 170 . . . which machines easily.

	C	Mn	Si	Cr	Mo
Typical Analysis	0.07 max	0.40	0.20	4.50	0.45

The nearest Bethlehem sales office or tool-steel distributor will gladly tell you about this hobbing steel and other Bethlehem Tool Steels for both hobbed and machined cavity molds. Write today for our new booklet, "Tool Steels for the Plastics Industry."

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation

Export Distributor:
Bethlehem Steel Export Corporation

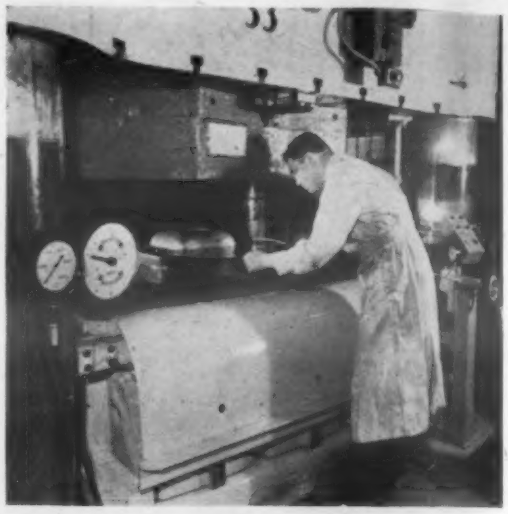
BETHLEHEM STEEL

Bethlehem SUPERSONIC TESTED Tool Steel

New Materials and Equipment

trol of the pressure curve for the forming cycle of the part. Close control prevents formation of wrinkles and reduces springback to a minimum. In addition to simple draw operations, the Marform process can be used to form and trim flanged parts and to shear, as well as form, in the same operation.

The Marform units are said to have



This metal forming unit developed by Glenn L. Martin Co. is being manufactured by Hydropress, Inc.

several advantages over both the Guerin process and the use of steel draw dies. In the Guerin process, where rubber is used as the female part of the tool, there is no pressure applied before motion of the press takes place. Thus, wrinkles can form in the metal with the initial movement of the press before any pressure is available to prevent their formation. By way of contrast, in a steel die a given pressure must be employed by the use of springs and air cylinders, and there is very little control over this pressure during the forming operation.

The Marform process overcomes the disadvantages of the Guerin process in that pressure can be built up in the machine by the movement of the press before any forming of the metal takes place. This process also eliminates the difficulty of lack of selectivity of pressures available in a steel die since the pressures can be varied infinitely and automatically in the stroke of the machine.

Use of rubber as the female portion of the tool in the Marform units provide a cushioning effect, preventing rapid application of strain at any point on the metal. The rubber can also exert a lateral pressure, which is a direct result of the applied forming pressure; this lateral pressure tends to lock the metal already formed to the form block of the tool and thereby prevent an accumulation of strain at the form block radius.

New Materials and Equipment

Hydraulic-Powered Bender

A simple hydraulic-powered bending unit, claimed to handle all bending jobs in a metal working plant, has been developed by *O'Neil-Irwin Manufacturing Co.*, 237 Eighth Ave., Lake City, Minn. Known as the Di-Acro Hydra-Power Bender, it is

Shown here is the Model No. 6 Di-Acro Hydra-Power Bender.

suitable for forming simple, compound and reverse bends in tubing, angle, channel, extrusions, moldings, strip stock, bus bars, round or square rods, and all other solid ductile materials.

The basic design of this equipment provides a driving spindle on which either of two different set-ups—Model 6 or Model 8—can be easily mounted.

●

Testing & Inspection

Inspection Instrument

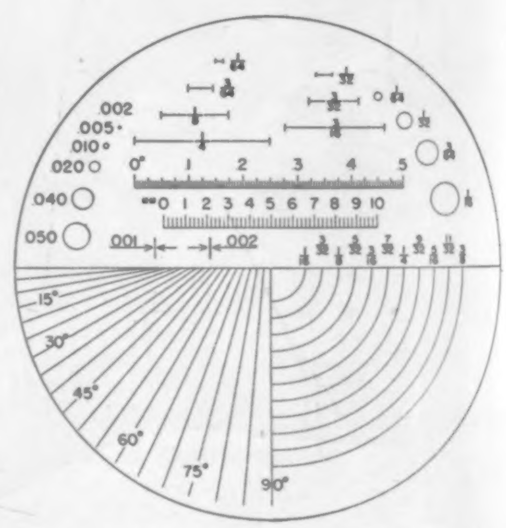
A multi-purpose inspection instrument, called the Pocket Comparator, is being marketed by *National Tool Co.*, 11200 Madison Ave., Cleveland 2, Ohio. It is a precision optical measuring instrument for the inspection of small parts or small dimensions on large parts.

The Pocket Comparator is said to eliminate the need for different devices for checking linear measurements, circles, angles, radii, etc., as it performs all of these functions. It permits the inspector to use a magnifying lens to compare the part to be checked against a finely calibrated pattern

New Materials and Equipment

or reticle. The lens is a triplet-design aplanatic type of great accuracy and has a magnification of 7 to 1.

The instrument can be separated in the middle for cleaning of the interior optical surfaces or for adjusting focal length to



Pictured above is the Pocket Comparator and the measuring pattern.

meet the eye requirements of the individual user. Transparent plastic construction is used between lens and reticle to permit entrance of light on the reticle and the workpiece. The Comparator was developed and is manufactured by Bell & Howell Co.

Strain Analyzer

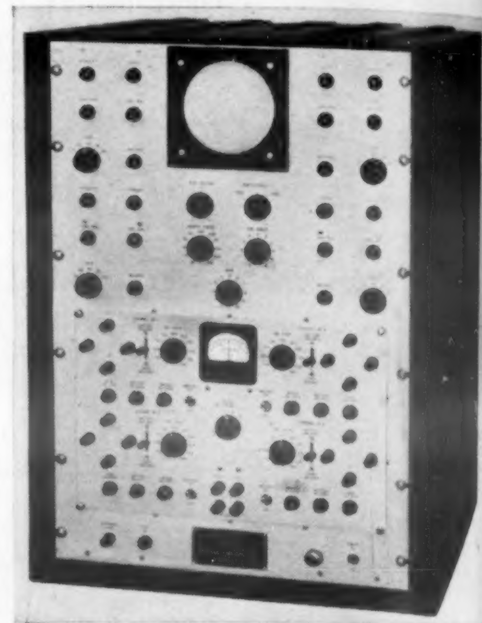
An instrument, called Strainalyzer Model H-42 and designed for the study of vibration strain and dynamic stresses, has been introduced by *Electronic Tube Corp.*, 1200 E. Mermaid Lane, Chestnut Hill, Philadelphia 18, Pa.

The new instrument is composed of four units: indicator, indicator power supply, camera and camera speed control. It is designed to work with Baldwin SR-4 re-

New Materials and Equipment

sistance strain gages, 60 to 1000 ohms.

The equipment can be used for (1) instantaneous strain measurements under steady static and impact loading conditions, (2) instantaneous load, pressure and torque measurements with SR-4 strain gage type



Vibration strain and dynamic stresses are determined by this Strainalyzer Model H-42.

devices, (3) vibration studies of rotating and reciprocating mechanisms, (4) evaluation of the physical characteristics of various materials under impact conditions, and (5) measurement of modulus of elasticity as related to acoustic propagation characteristics of the specimen.

Machinability Testing

A constant-pressure lathe, designed to give steel distributors and their customers a simple and rapid test of machinability, is being marketed by the *Monarch Machine Tool Co.,* Sidney, Ohio.

The machinability testing method is based on the use of a Monarch lathe specially equipped to provide fixed tool pressures with a constant component in the horizontal direction. It has been found that, under this condition, steels of different machining quality cut at different rates. The method was developed in the course of a cooperative research project conducted at Battelle Memorial Institute under the sponsorship of Carnegie-Illinois Steel Corp.

This testing method is claimed to do the following:

1. Provide a high order of sensitivity. For example, it will disclose difference in cutting quality between samples of the same grade of free-cutting steel.

2. Provide adequate reproducibility of constant-tool-pressure machinability test rat-

New Materials and Equipment

ings in comparatively close agreement with tool-life test values when sampling is reliable.

3. Provide machinability indices which are in agreement with ratings obtained by conventional laboratory tool-life tests and large-scale commercial machining tests.

4. Offer a relatively quick, dependable means of rating the cutting qualities of free-cutting steels with the use of small samples, providing an indication of the probable performance of these materials in commercial machining operations.

In addition to the provision for application of predetermined horizontal tool pressure, the Monarch lathe differs from a

Shown above is the Monarch lathe adapted for machinability measurements.

standard machine in two respects. The tool carriage is disconnected from the fixed feed mechanism and is mounted on anti-friction bearings, so as to move easily along the bed. And a mechanical counter is used to record the number of spindle revolutions and to measure tool travel.

The machinability-testing lathe is powered by a 5-hp. motor and provides 16 spindle speeds ranging from 24 to 1000 rpm. It has a 16½-in. swing and 30 in. between centers. The spindle, bored out, accommodates bars up to 1½-in. dia.

Chemical Analysis

An instrument developed at Battelle Memorial Institute and manufactured by *Eberbach & Sons Co.*, Ann Arbor, Mich., is claimed to cut time for analytical operations in metal-producing plants as much as 75%. It is also said to make practical analyses, which have been considered too costly for routine laboratory use.

The instrument, called a Dyna-Cath, employs a novel magnetic circuit with the

New Materials and Equipment

mercury-cathode principle for separating interfering metals. It is said to be particularly useful for determining aluminum in steel and in zinc-base alloys; zirconium in iron

A novel magnetic circuit is the key to the improved performance offered by the Dyna-Cath.

and steel; and uranium, alkaline earths and alkali metals in alloys of iron, copper, nickel, chromium, zinc, molybdenum and other metals.

General

Pyrometer for Irons

Harry W. Dietert Co., 9330 Roselawn Ave., Detroit 4, Mich., has made available a pyrometer, called "Ferrotemp," for measuring the temperature of molten white and gray irons in large or small ladles.

The 9-lb. unit has an overall length of 64 in. The temperature scale of the meter has sub-graduations of 20 deg., allowing interpolation to 10 deg. in a range extending up to 3000 F. Operating cold, the time required for a temperature reading of a ladle of metal need not exceed 45 sec.; when the unit is warm from previous use, this time can be cut to 25 sec.

Fatigue Testing

Smooth, stepless acceleration from 10 to 100 cycles per sec. is claimed for the Model 100-HA-T Vibration Fatigue Testing Ma-

New Materials and Equipment

chine developed by *All American Tool & Manufacturing Co.,* 1014 W. Fullerton Ave., Chicago 14, Ill. This control can be

Studies aimed at controlling vibration effects on materials can be carried out with this fatigue tester.

accomplished manually or automatically. The infinite speed range is provided by a General Electric Thy-Mo-Trol electronic drive.

Portable Hardness Testers

R. Y. Ferner Co., 110 Pleasant St., Boston 48, Mass., has announced a new line of portable hardness testing instruments for metals, plastics and industrial finishes. Two of the principal instruments offered are improved models of the Dwarf Brinell Tester (static method) and the Duroskop Hand Tester (dynamic method).

Through the use of three sizes of Brinell balls and by varying the pressures exerted, the improved Dwarf instrument is claimed to measure the true hardness of steel, iron, lead and copper (including alloys and castings) more accurately than standard laboratory equipment commonly used.

The Ferner equipment includes a convenient reading scale for measuring the impression. Auxiliary equipment includes accessories for bringing the standard Brinell method into the hard alloy steel range and a hydraulic unit by which precise loading can be attained.

Sorter for Steel

An instrument developed by the Research Dept. of *Jones & Laughlin Steel Corp.* for separating semi-finished and finished steel products that have become mixed is now being marketed by *Fisher Scientific Co.,* 717 Forbes St., Pittsburgh 19, Pa.

The Steelsorter differentiates between all types of carbon steel by responding to magnetic differences in the metals, regardless of

New Materials and Equipment

whether the differences are chemical, physical or metallurgical in nature. It is intended to solve the problem which arises when steel of identical appearance and diameter but of different chemical composition occasionally becomes mixed.

The unit is designed to separate round bars, flat bars, hexagonal bars or tubes equally well. Operation is simple: the sample is inserted through the opening in the test unit, the button on the top of the unit depressed, and the dial read. In separating mill stock, it is important only that the operator remember that the cross-sections of the pieces must be similar. Small parts of the same size can also be sorted if they are placed in the same position in the test unit. It is claimed that one man using the Steelsorter can separate several hundred small samples per hour.

The principle of operation of the Steelsorter lies in its sensitivity to changes in permeability, hysteresis and eddy current losses in the steel. These magnetic properties are affected by alloy composition, strains due to cold work on rapid quench, grain size, specimen size, heat treatment and aging. Thus, these differences change the efficiency of the steel sample as a magnetic coupling medium between the primary and secondary coils of the test piece unit. The varying voltage induced in the secondary coil is shown on the meter, indicating whether or not the pieces being tested are similar.

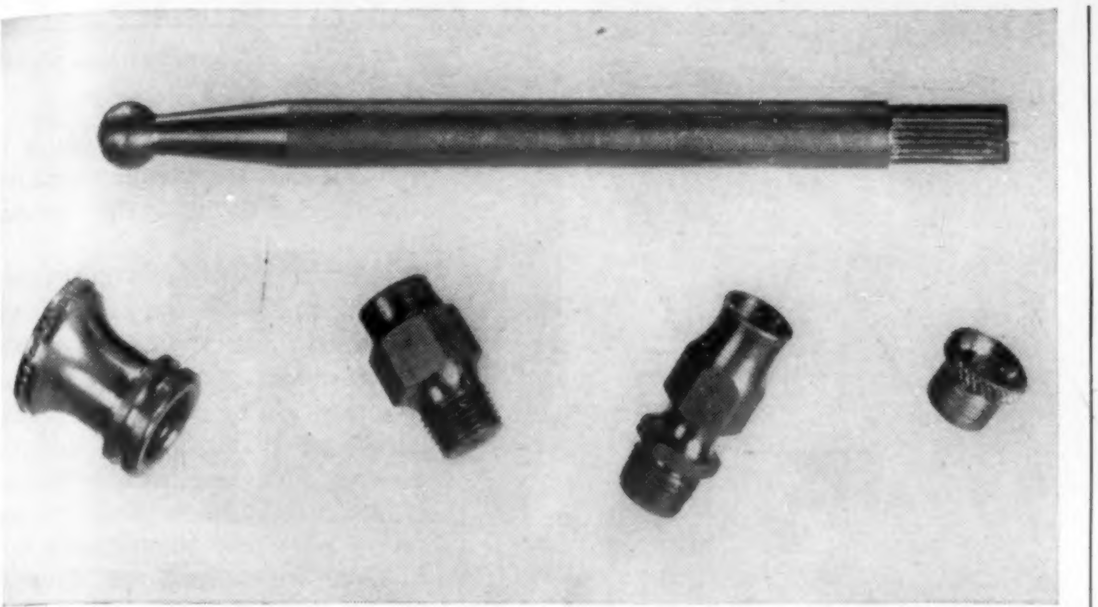
The Steelsorter distinguishes magnetically between steels of similar appearance but different manufacturing history.

The Steelsorter is equipped with five different test-pieces, since the nearer the diameter of the specimen is to that of the unit, the more efficient the instrument. These sizes have cylindrical openings with diameters of ½, 2, 4, 6, and 9½ in. The instrument is portable and operates from 110 v., 50 to 60 cycles a.c.

COPPER ALLOY BULLETIN

REPORTING NEWS AND TECHNICAL DEVELOPMENTS OF COPPER AND COPPER-BASE ALLOYS

Prepared Each Month by BRIDGEPORT BRASS COMPANY "Bridgeport" Headquarters for BRASS, BRONZE and COPPER



Screw machine items illustrating knurling and roll threading operations.
Courtesy, Seymour Brass Turnings Company.

Free Machining Brass Rod Suitable For Roll Threading

Roll threading and knurling in the primary screw machine operation have done much to reduce the cost on thousands of precision and ornamental parts.

To keep pace with this trend, it has been necessary for the brass fabricator to carefully control temper to give free machining rod sufficient ductility to permit cold deformation of this type and at the same time maintain the highest machinability rating.

Bridgeport's Ledrite 6, free turning brass rod, was used for the parts shown in the accompanying photograph. These parts were made by Seymour Brass Turnings Company, Seymour, Conn., and are good examples of straight, diamond and bead knurling as well as thread rolling.

Stop Supports Long Piece

The long part at the top is an automobile mirror swivel arm. It is five inches long and 3/8" in diameter. The stock is fed out in a #2 Brown & Sharpe about 1", box turned, straight knurled and drilled from the turret. It is fed out again to a turret stop which takes the knurled diameter and rests against the turned shoulder to give support for the ball forming operation and cutoff. The work is turned at around 350 feet per minute and the feed is 0.0015" per revolution.

The two air-vent valves for heating systems are made from hex rod. Besides deep drilling and multiple forming, the threads are rolled in the screw machine and are 3/8" pipe. No difficulty is encountered in using the free machining Ledrite 6 Brass rod. The cord bushing has a diamond knurl and the threads are rolled. The knurl on the lamp finial has a ball knurl which is produced by actual deformation under pressure of the knurling tool. A narrow ridge is turned by the forming tool on the large end for knurling. The material shows no signs of cracking or splitting.

Temper Controlled

In sizes from 3/8" up, the temper of this rod stock is kept low enough to permit knurling and maintain free machining of its properties. If there is no knurling or roll threading involved, Bridgeport can supply rod in a higher temper. Screw machine fabricators, however, report little or no difference in the machining characteristics of the two rods despite the difference in temper.

In rod sizes below 3/8", Bridgeport rod is slightly harder in temper to insure against bending and buckling during machining. When using sizes below 3/8" if any difficulty is encountered in roll threading or knurling, it may be necessary to change to a softer temper or switch to another alloy which is more ductile such as Ledrite 2, which contains slightly less lead with the copper increased correspondingly. This alloy is also useful where exceptionally accurate knurls and rolled threads are demanded as in the precision instrument field. But for the majority of cases the standard free cutting brass rod is very satisfactory.

When selecting alloys, especially where intricate forming, roll threading or knurling is involved, Bridgeport's Laboratory should be consulted. Also make use of its valuable experience to help you solve other metal problems such as improving products or reducing costs.

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AIME Papers ....

continued from page 49

contrast to substitutional solutes, it was shown that the element with the lowest solubility has the greatest strengthening effect.

The data now available on titanium and titanium-base alloys are sufficient to indicate that their engineering properties are adequate to insure them a position of importance among construction materials. In addition to having good engineering properties, however, a structural material must be relatively inexpensive if it is to have widespread use. For this reason, "A Continuous Method of Producing Ductile Titanium," reported by P. J. Maddex and L. W. Eastwood, of Battelle Memorial Institute, is of considerable interest.

The method, not yet fully developed, involves the continuous production of titanium or titanium alloy ingots, employing magnesium and titanium tetrachloride as the raw materials. It is actually a two-step process ultimately to be carried out in a single integrated unit. Thus, the products from the reaction chamber will be permitted to run continuously from the bottom directly into an arc furnace. In the arc furnace, the titanium will be melted and the magnesium chloride and unreacted magnesium volatilized, condensed and removed from the furnace chamber while a continuously formed titanium ingot is withdrawn from the bottom of the furnace. The authors anticipate that titanium produced by this method may be of somewhat greater purity than that produced by present batch methods.

In connection with the production of titanium, AIME members also heard a report on "Recent Practice at the Boulder City, Nev., Titanium Plant" by F. S. Wartman, H. C. Fuller and Don H. Baker, Jr. The Bureau of Mines investigators described equipment and techniques used for the production of crude titanium in 200-lb. batches by reduction of purified titanic chloride with magnesium.

Zirconium Development

Although zirconium has not captured the imagination of the materials

News Digest

engineer to the same extent as titanium, its development has lagged only slightly behind that of titanium. Recent progress in developing economical production methods for zirconium was described in a Bureau of Mines paper, "Production of Malleable Zirconium on a Pilot Plant Scale," prepared by W. J. Kroll, W. W. Stephens and H. P. Holmes. The authors described a plant in which zirconium can be produced in 150 lb. per batch at a reasonably low cost. They believe that the size of the present equipment can be increased considerably before difficulties with heat dissipation will appear. This belief is given credence by the existence of titanium reactors of 200 lb.; actually, the heat evolved in reducing zirconium chloride is much lower than that for titanium chloride.

The methods of producing zirconium are practically identical with those for titanium. In the present pilot plant, zirconium ingots can be produced at $6.82 per lb. Compared to titanium, the higher cost of the zirconium in the ore should be more than compensated by the higher consumption of reducing agent for the titanium. Thus, the authors expect that the future price of zirconium will probably be the same as that of titanium.

New Steelmaking Process

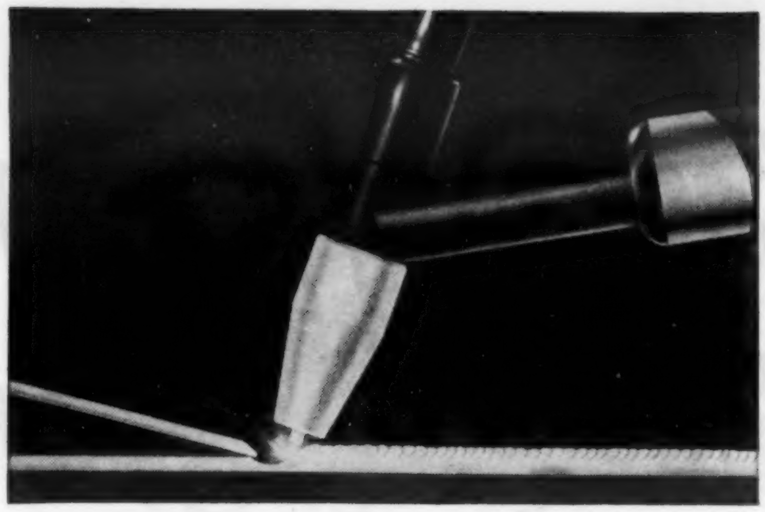
Working details of a new, fast steelmaking process were presented by C. E. Sims, of Battelle Memorial Institute, and F. L. Toy, of Carnegie-Illinois Steel Corp., in "Experimental Operation of a Basic-Lined Surface-Blown Hearth for Steel Production." Sponsored by Carnegie-Illinois, the new method has been named the "Turbo-Hearth" process.

Significance of this development rests on the following conclusions reached by the authors:

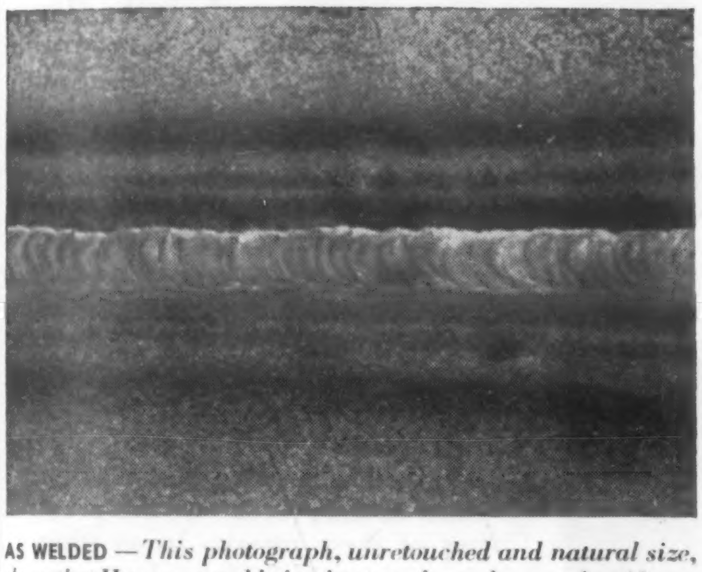
1. Steel can be made by surface-blowing on a basic-lined hearth. Oxygen can be added to the standard air blast if desired.
2. Mechanical properties of "Turbo-Hearth" steel are equal to those of open hearth steels of the same grade.
3. Standard basic pig iron is entirely suitable as a raw material.
4. Average time of heat is 12 min. Thus, a hearth of 30-ton capacity is capable of making much more steel in

Weld Sheet Steel with the HELIARC torch

Trade-Mark



and wipe out one complete operation



AS WELDED — *This photograph, unretouched and natural size, shows that* HELIARC *welds in sheet steel are clean and uniform.*

There is no spatter or flux, so you save cleaning costs when you switch to the HELIARC process for welding sheet steel. And you keep the advantages of high speed, and minimum distortion that are characteristic of arc welding. Any manual arc or gas welding operator finds welding with a HELIARC torch easy to master.

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We are ☐ (are not ☐) now using inert gas-shielded welding

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Company..

City................................ State...........

News Digest

a day than a 225-ton standard open hearth furnace.

5. "Turbo-Hearth" steel contains a minimum of such undesirable elements as sulfur, phosphorus and nitrogen.

The process is actually a *basic* Bessemer process as opposed to the *acid* Bessemer process which first revolutionized the steel industry in this country. No external fuel is needed as the heat is provided through oxidation of the impurities in the liquid. The experimental Turbo-Hearth chamber is similar to the Bessemer converter in that it is suspended on trunnions; its spout can be raised during the heating period and lowered for charging and pouring.

Magnesium-Rare Earth Alloys

In the past it has been found that the strength and creep resistance of magnesium at elevated temperatures are greatly enhanced by the addition of cerium in the form of Mischmetal, which contains all the rare earth elements in essentially the same proportions as they occur in the principal ore of these metals. In an effort to determine which of the elements present in Mischmetal contributes the greatest effect in developing high temperature strength, Thomas E. Leontis, of Dow Chemical Co., investigated "The Properties of Sand Cast Magnesium-Rare Earth Alloys," selecting the following alloy systems:

1. Magnesium-didymium
2. Magnesium-cerium-free Mischmetal
3. Magnesium-praseodymium-lanthanum
4. Magnesium-Mischmetal
5. Magnesium-cerium
6. Magnesium-lanthanum

The author found that, although all all the rare earth metals investigated enhance the strength, hardness and creep resistance of magnesium at room and elevated temperatures, there are marked differences among the metals in the degree to which they improve these properties. Thus, the alloys are listed above in order of decreasing tensile properties at room and elevated temperatures and creep resistance at 400 and 500 F. The relative effects on creep resistance at 600 F depend upon the composition level and, to a certain extent, upon grain size.

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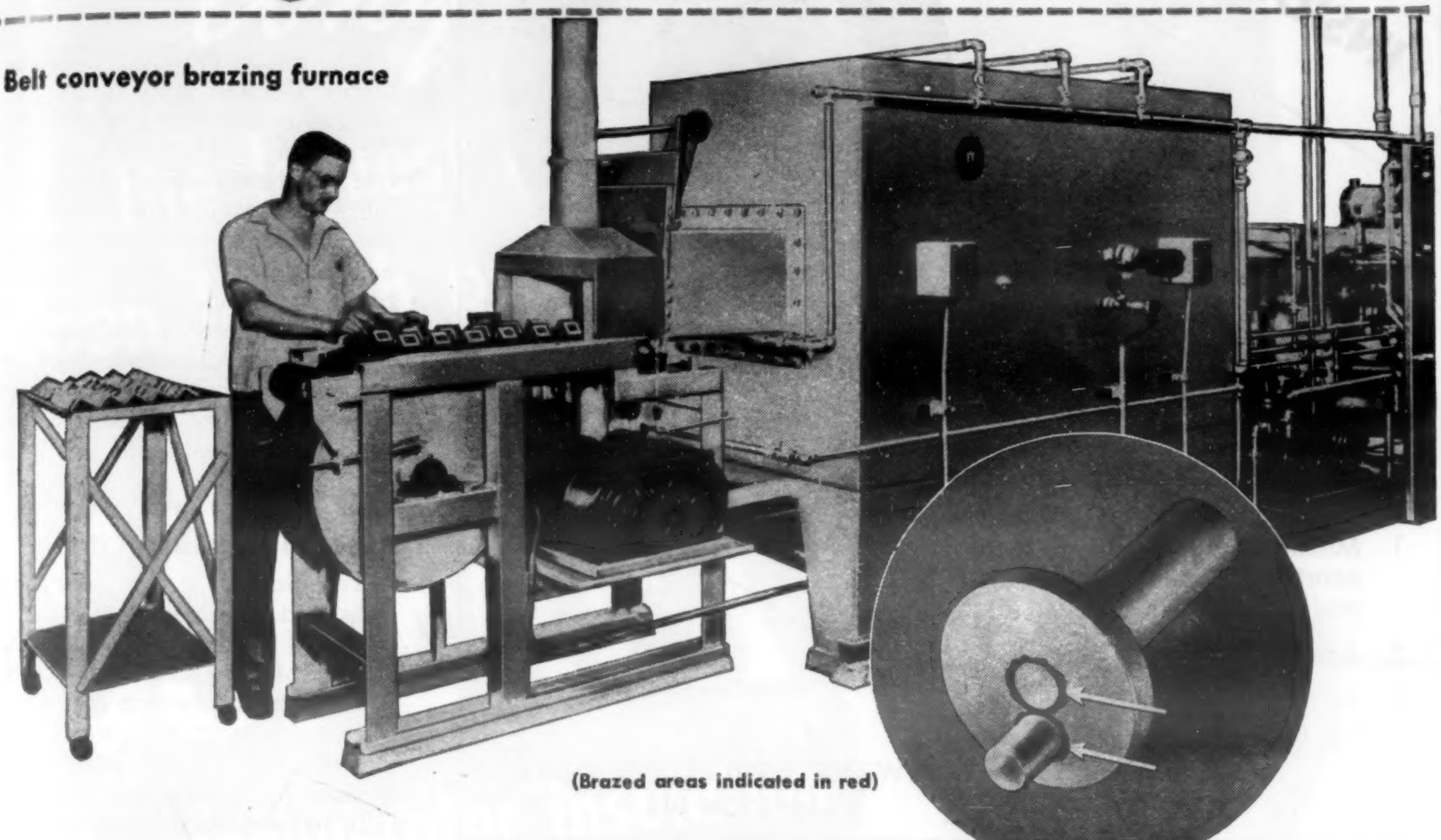
Westinghouse

Belt conveyor brazing furnace



(Brazed areas indicated in red)

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GAS AND ELECTRIC
Furnaces

News Digest

The results show that considerably higher elevated temperature properties can be developed in magnesium-didymium and magnesium-cerium-free Mischmetal alloys than those exhibited by magnesium-Mischmetal alloys. Although these advantages may not hold over the entire temperature range, the author believes these alloys warrant serious consideration for commercial applications. Further development of these alloys will depend upon availability of the rare earths and a possible reduction in their cost.

Powdered Magnesium Extrusion

Techniques for the "Extrusion of Powdered Magnesium Alloys" were described by R. S. Busk and T. E. Leontis of Dow Chemical Co. They stressed the importance of the use of atomized powder, a new mechanism termed "interference hardening," a method for combatting stress-corrosion, and a method for increasing the hot-short speed of extrusions.

They found that although the alloy ZK60+0.5% calcium has excellent mechanical properties, it can be extruded at only 1 ft. per min. Its range of properties is 3 to 13% elongation, 35,000 to 53,000 psi. tensile yield strength, 34,000 to 50,000 psi. compressive yield strength, and 45,000 to 56,000 psi. tensile strength. Addition of 50% M1 to this alloy raises the permissible extrusion rate to 5 ft. per min., but the properties are significantly lower. Thus, 9 to 17% elongation, 26,000 to 44,000 psi. tensile yield strength, 26,000 to 41,000 psi. compressive yield strength, and 40,000 to 49,000 psi. tensile strength are obtained. However, ZK60+0.5% calcium contains zirconium which can be made to undergo an interference-hardening reaction by addition of aluminum. With the addition of 12% magnesium-aluminum eutectic to the second alloy, the permissible extrusion speed remains at the 5 ft. per min. level and a better combination of properties is obtained. Elongation ranges from 3 to 12%, tensile yield strength from 44,000 to 47,000 psi., compressive yield strength from 42,000 to 48,000 psi., and tensile strength from 51,000 to 53,000 psi. In addition, this alloy can be expected to be no more sensitive to stress corrosion than M1.

Why

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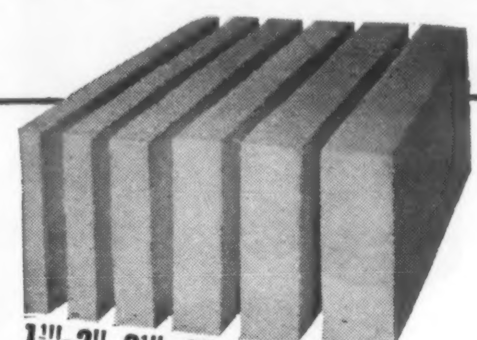
The large size of the Superex blocks saves construction costs



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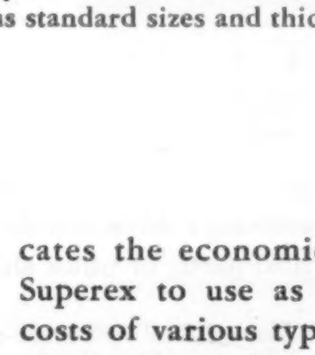
To help you gain the greatest savings from Superex, Johns-Manville has prepared an engineering report, "Open Hearth Regenerators—a comparison of various insulation specifications." This report indicates the economic thickness of Superex to use as related to the costs of various types of fuels. To obtain this booklet, write Johns-Manville, Box 290, New York 16, N. Y.



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News Digest

Prestraining Temperatures

According to T. E. Tietz, R. A. Anderson and J. E. Dorn, of the University of California, recent investigations have conclusively shown that the strain-hardened state of metals depends upon the temperature and strain rate of prestraining as well as on the total plastic strain. The well known effect of the strain-hardened states of metals on their recovery rates suggested that a more complete identification of the effect of strain rate and temperature histories on the strain hardening of metals might be obtained from recovery tests.

The results of such tests are reported in a paper entitled "Effect of Prestraining Temperatures on the Recovery of Cold Worked Aluminum." The authors selected pure aluminum for these studies in order to minimize the effect of such factors as strain aging on the interpretation of the data. Conclusions reached by Tietz and his co-workers are as follows:

1. The mechanical properties of cold-worked metals depend not only on the instantaneous values of the strain, strain rate and temperature but on the entire past history of temperature and strain rate during prestraining.
2. Neither the instantaneous value of the total strain nor the instantaneous value of the flow stress under stated conditions of strain rate and temperature are adequate for characterizing the strain-hardened state.
3. Specimens of a metal can be so prestrained at various temperatures that the same flow stress is obtained when they are subsequently tested at the same instantaneous temperature and strain rate. Those prestrained at the higher temperatures require greater amounts of prestrain.
4. Although such specimens have the same instantaneous flow stress, those prestrained at the higher temperatures have greater instantaneous rates of strain hardening.
5. The recovery rate of pure aluminum depends upon the temperature of prestrain; specimens prestrained at the lower temperatures exhibit much higher rates of recovery.
6. These observations appear to suggest that lower temperatures of prestraining induce the formation of smaller or otherwise more readily activated dislocations.

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Cold-Worked Aluminum Recovery

A closely allied paper, entitled "Some Observations on the Recovery of Cold Worked Aluminum," was presented by T. V. Cherian, P. Pietrokowsky and J. E. Dorn, of the University of California. One of the difficulties encountered in connection with recovery is the wide differences in the recovery rates of various properties. Major interest has generally been directed toward the recovery of the mechanical properties such as hardness, yield strength and tensile strength. Current recognition of the fundamental importance of the true stress-true strain curve, however, led the authors to investigate the effect of recovery treatment on the true stress-true strain curves in tension.

Commercially pure aluminum in the form of 0.10-in. thick rolled sheet of 2S-O alloy was selected by the investigators. Their results can be summarized as follows:

1. After recovery at low temperatures (90 and 212 F), cold-worked aluminum exhibits a low initial flow stress upon restraining. But after an additional strain of about 0.04, the flow stress is restored to essentially that value which would have been obtained if the specimen had not been recovered. This is called metarecovery.

2. At higher temperatures (300 and 400 F) not only is metarecovery observed, but a permanent decrease in the flow stress is obtained such that the stress-strain curve for the recovered metal is below that for the virgin metal at the same total strain for all strains. This is called orthorecovery.

3. The kinetics of metarecovery and orthorecovery appear to be distinctly different. This suggests that during work-hardening at least two kinds of imperfections are introduced, one which is rapidly recoverable, and a second which is more slowly recoverable. This assumption rationalizes the observed differences in recovery rates of different properties.

Brass Annealing Cracks

Brass mills are familiar with a recurring problem manifested during deformation of annealed metal as an opening up of cracks which are suggestive of a grain boundary pattern. In "Intergranular Parting of Brass During Anneals" F. H. Wilson and

this new plant

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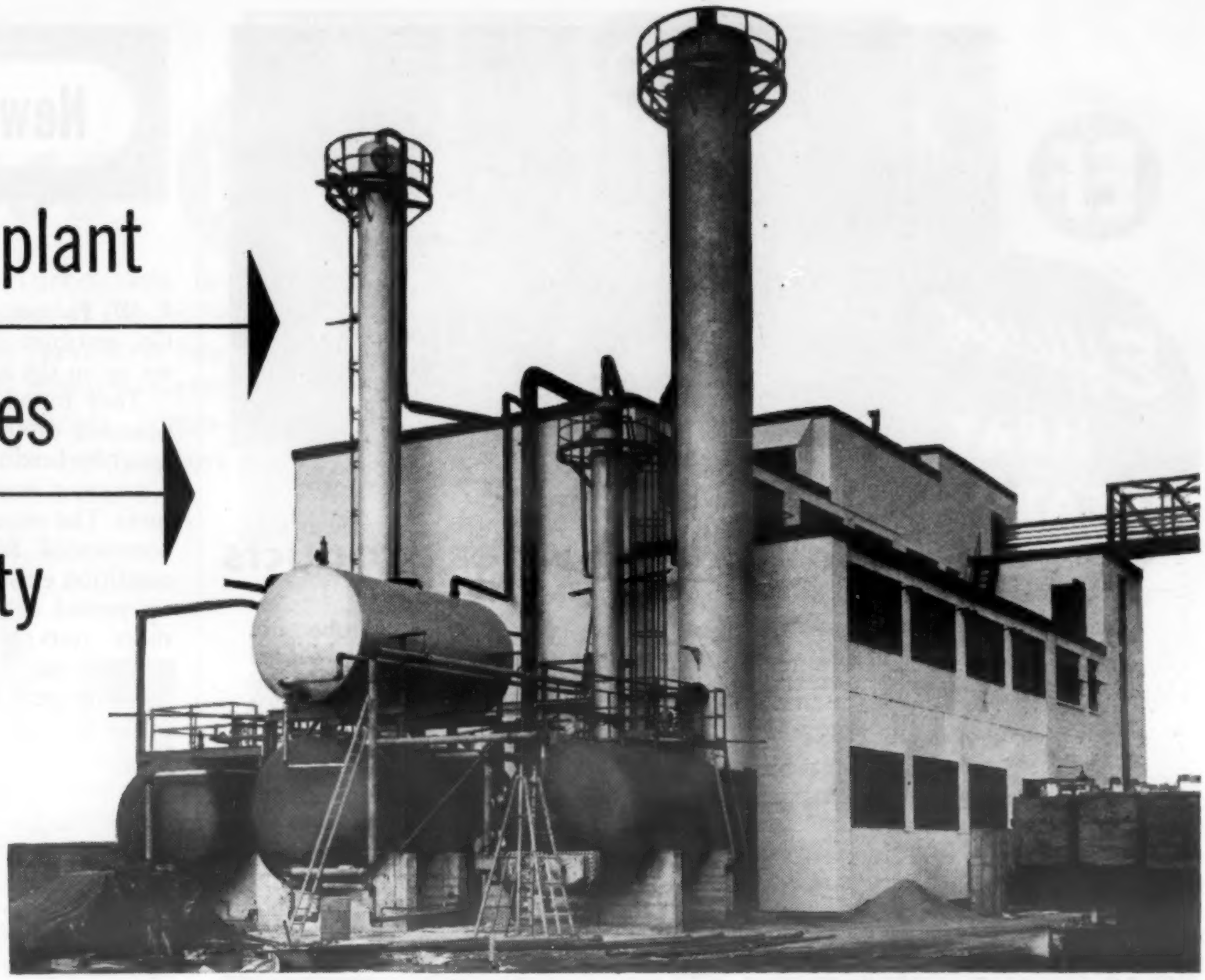

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E. W. Palmer, of the American Brass Co., attribute the problem to stresses set up in the annealing process.

They found that the structural appearance of this defect can be duplicated by holding tensile specimens at a constant stress at elevated temperatures. The most probable time during commercial fabrication that such a condition exists is during the heating-up period of an anneal and the authors' tests appear to support this explanation. Their tests also showed the importance of grain size, since both the tendency toward intergranular parting and the tendency toward slow relief of stress are increased with increasing grain size.

The authors suggest that the tendency toward intergranular parting can be minimized by:

1. Minimizing internal stress left by cold working.
2. Keeping grain size down.
3. Providing for uniform heating.
4. Heating slowly enough to permit some stress relief before cracking temperatures are reached.
5. Placing the work in the furnace in such fashion that surfaces known to be internally stressed in tension reach temperature first.

Phosphorus and Molybdenum

In previous work, M. Baeyertz, W. F. Craig, Jr. and J. B. Sheehan, of Armour Research Foundation of the Illinois Institute of Technology, had observed a progressive decrease in toughness when the phosphorus content of 5140 steel was raised from 0.020 to 0.036% (*i.e.*, from a moderate phosphorus level to one higher but still within the AISI-SAE specification for this grade). Toughness of the tempered martensitic structure of the steel was evaluated by the transition temperature determined by V-notch Charpy tests. The investigators found that replacement of a part of the chromium in 5140 by molybdenum provided a factor of safety against loss of toughness caused by phosphorus, especially where the steel was cooled slowly after tempering.

In "The Effects of Molybdenum and Commercial Ranges of Phosphorus upon the Toughness of Manganese Steels Containing 0.40% Carbon," these same researchers investigated the possibility of obtaining similar

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improvement in 1340 by replacing part of the manganese with molybdenum. Heats were made at different phosphorus levels in a series that began with 1340 and ended with steels containing 0.32 to 0.35% molybdenum with 0.82 and 0.90% manganese.

The authors of this paper conclude that replacement of a part of the manganese in 1340 steel by molybdenum, in proportions required to maintain the hardenability of the grade, reduces the loss of toughness caused by phosphorus in tempered martensite. Furthermore, the tolerance for phosphorus provided in tempered martensite by partial replacement of manganese by molybdenum depends upon the amount of the replacement and the heat treatment of the steel. Appreciable improvement resulted from as little as 0.06% molybdenum. With 0.18% molybdenum, toughness was virtually unaffected by the severe embrittling treatments employed in this work, even with a phosphorus content of 0.035%.

Phosphorus and Nitrogen

"Some Effects of Phosphorus and Nitrogen on the Properties of Low Carbon Steel" were determined by G. H. Enzian, of Jones & Laughlin Steel Corp.

The effects of these elements on the properties of low carbon steels are important considerations to the user of such material, as these two elements represent the principal composition difference between Bessemer and open-hearth grades. Furthermore, open-hearth steels themselves may vary considerably in nitrogen content, and, in addition, appreciable amounts of rephosphorized open-hearth steels are being used at the present time in some low alloy, high strength grades and in certain other cases.

Study of the tensile and impact properties, sensitivity, and strain aging of a number of induction furnace heats containing varying amounts of phosphorus and nitrogen seems to indicate that the two elements exert additive effects and, with the exception of strain aging behavior, the relative amounts of both elements must be considered in evaluating either. In the case of strain aging, phosphorus apparently contributes so

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little that the aging behaviors of high and low phosphorus steels with the same nitrogen contents are virtually indistinguishable.

The author also concludes that:

1. Nitrogen variations in low phosphorus steel have a greater effect on its properties than similar variations in high phosphorus material.
2. Phosphorus variations in low nitrogen steel produce a greater change in properties than similar variations with high nitrogen contents.

These observations, however, do not hold for steels deoxidized with aluminum and certain other elements.

Most of the papers in this summary have been published in full in the Journal of Metals, starting in the Dec. 1949 issue. Further information on the availability of these papers can be obtained from the American Institute of Mining & Metallurgical Engineers, 29 West 39 St., New York 18.

Magnesium Rolling Mill

Greatly increased demand for magnesium sheet in airplane construction and other phases of the national security program has led to the establishment of a new division for the rolling of magnesium sheet at Aluminum Co. of America's New Kensington, Pa., works. Magnesium rolling operations have been conducted at this plant in the past, but were discontinued in 1947 because of the sharp drop in demand for magnesium sheet after the war.

Studies Show Fatigue Cracks Develop Below Endurance Limit

Tests of two shipbuilding steels have shown that fatigue cracks develop and propagate at cyclic stresses below the endurance limit and that such cracks materially raise the transition temperature. The studies, based on B and W steels, were carried out by J. M. Lessells and H. E. Jacques, of Massachusetts Institute of Technology and reported in *The Welding Journal* (February).

When fatigue-impact specimens were cyclically stressed so as to avoid fatigue cracks, the resulting transition curve showed little deviation from the original curve. The authors con-

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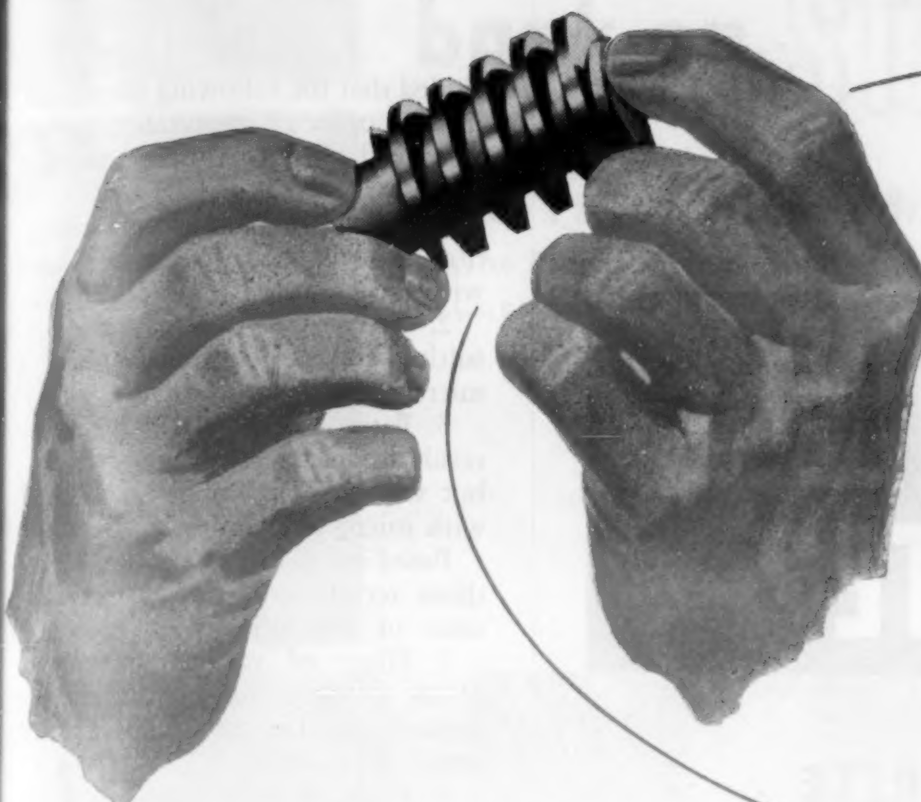

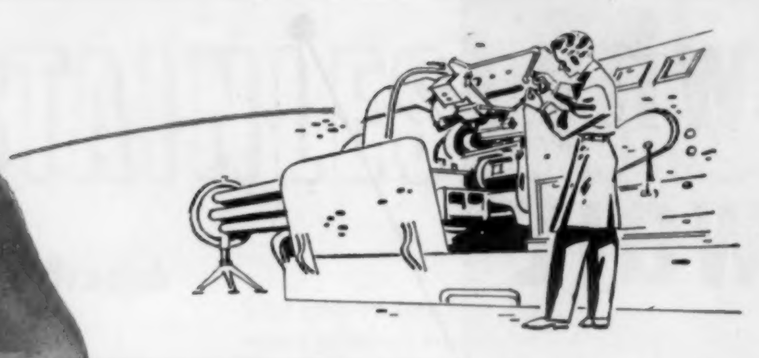

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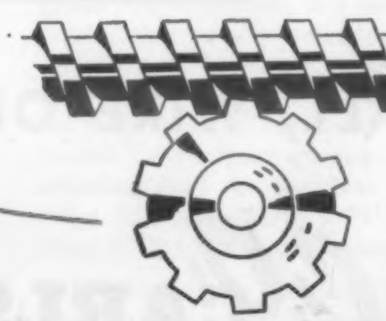

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Produced by Republic's Union Drawn Steel Division, these bars are unsurpassed for close tolerance, accuracy of section, fine surface finish and UNIFORM MACHINABILITY. They are strong, tough, and uniform in response to hardening treatment. They're made to withstand shock, strain, wear and heavy loads without weakening.

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cluded that the following phenomena, in their order of importance, produce a marked effect on impact transition curves:

1. Fatigue damage accompanied by high stress concentrations associated with fatigue cracks.
2. Gross plastic deformations resulting probably in an increase of micro stress concentrations.
3. Fatigue damage which does not result in macro stress concentrations but which is undoubtedly associated with micro plastic deformations.

Based on these conclusions, the authors recommend further investigations of the following phenomena:

1. Effect of various amounts of plastic deformation (prestraining in tension) on the transition temperature.
2. Effect of cyclic stress amplitude, both in direct (axial) loading as well as bending, on rate of crack propagation.
3. Effect of cyclic stresses (bending and direct loading) on transition temperature at amplitudes below those which produce cracks.

Although their tests were undertaken in connection with current investigations of the causes of ship fractures, the authors believe the studies recommended above should be carried out on a variety of ferrous and nonferrous alloys.

Greatest Synchro-Cyclotron Ready

The world's most powerful synchro-cyclotron, generating 385 million electron volts, is now in operation at Nevis, Irvington-on-Hudson, the New York site of Columbia University's new nuclear physics research center. The project was developed in cooperation with the Office of Naval Research and jointly sponsored by the Atomic Energy Commission. Construction of the laboratory was started in February, 1947, and completed last month.

New Reduction-of-Area Gage

More reliable data on some of the mechanical properties of metals and alloys at low temperatures are be-

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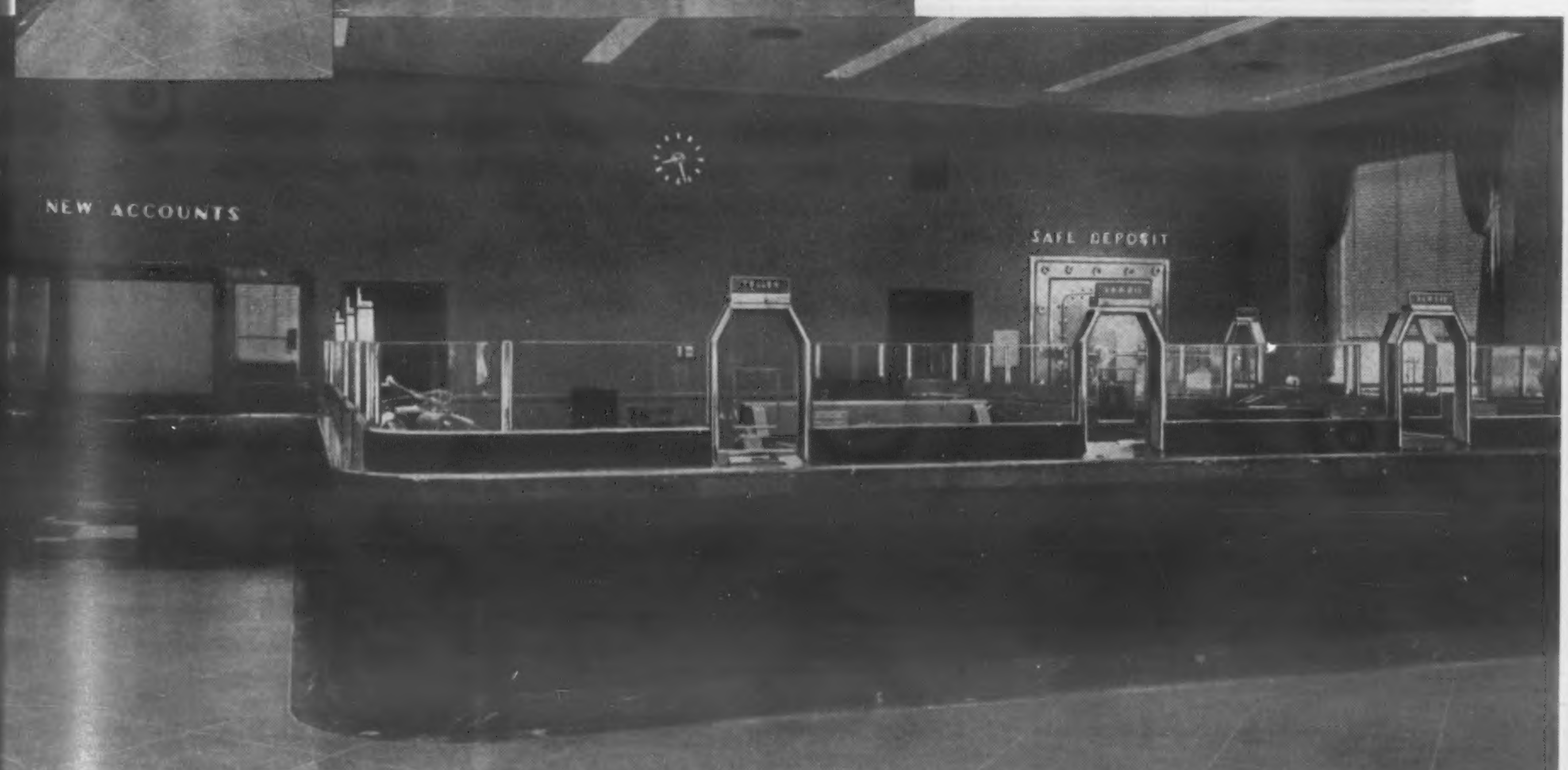

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CHEMICALS AND METALS

News Digest

lieved imminent with the recent development of a special reduction-of-area gage by G. W. Geil and N. L. Carwile, of the National Bureau of Standards.

For some metals, an accurate determination of the stress-strain curve from yield to maximum load cannot be made from extension measurements because the metal may contract locally before reaching the final maximum load. Moreover, simultaneous

The Bureau of Standards' new reduction-of-area gage accurately follows changes in diameter of specimens tested in refrigerants.

load and diameter measurements are essential for the determination of the complete true-stress: true-strain curves for metals tested in tension. The Bureau's new gage makes possible successive diameter measurements during the entire deformation of the specimen.

Atomic Power Plant Structures Raise Unique Materials Problems

Some of the unique materials problems encountered in designing structures to be used in atomic power plants were pointed out recently by Harry E. Stevens, of General Electric Co., in a talk before the Fort Wayne section of the American Institute of Electrical Engineers.

A nuclear reactor emits high-energy particles and radiations comparable with those that would be discharged from several tons of pure

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radium. Able to penetrate considerable thicknesses of any material, these particles may change the arrangement of the atoms of which a structure is made, and considerably alter its physical properties. Thus, a structural material which may be entirely satisfactory for ordinary engineering uses might be made unsuitable for prolonged operation in an atomic power plant.

Another question which must be considered is the capacity of a structural material to behave as a "neutron blotter." The atomic particles called neutrons, which are produced in large numbers in the reactor, are responsible for maintaining the chain reaction by which atomic energy is released. Control rods, which soak up these neutrons as a blotter soaks up water, are required to keep the reactor from running away. If many other parts of the structure act as neutron blotters, however, the supply of neutrons will be depleted and the power output reduced.

Materials for shielding the reactor so that radiations emitted will not be dangerous to personnel in the vicinity present another problem. Such shields must be thick enough to reduce the intensity of the rays by many thousands of times. If concrete is used, it must be many feet in thickness, but proper selection of materials makes it possible to cut shield size considerably. Such considerations as these make it necessary to investigate strange new structural materials for many atomic power plant applications.

Titanium Alloy Used in Jets

The Navy Bureau of Aeronautics has released a few details on a lightweight, titanium-base alloy now being used in jet aircraft. The alloy, containing 5 chromium and 3% aluminum, has been under development for four years. It is being used in parts of jet aircraft where strength and oxidation resistance at high temperatures are important, such as turbine blades, tailpipe shrouds, engine fire-walls and in the engine proper.

In addition to providing greater high-temperature strength than alu-

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minum and magnesium alloys, the new titanium alloy offers a better strength-weight ratio than alloy steel, thus making possible lighter aircraft.

News of Engineers

J. Ralph Macon recently joined the Pennsylvania Salt Manufacturing Co. as an engineer in the Market Research Div. Mr. Macon, formerly associated with the Electrochemicals Dept. of E. I. du Pont de Nemours & Co., Inc., will work on market development of new Pennsalt products for the metallurgical industry.

The election of *Lewis P. Tabor*, senior research engineer in the Franklin Institute Laboratories for Research and Development, as chairman of the Institute's highly important Science and Arts Committee has been announced. The Committee is responsible for choosing the scientists to whom special Institute medals are awarded each year. Mr. Tabor replaces *Laurence LePage* of the Adrian Bauer Advertising Agency, who resigned to undertake other duties for the Institute.

Dr. *Frederic W. Schuler* is now associated with National Research Corp., where he is engaged in metallurgical research.

Election of officers of E. F. Houghton & Co. occurred at a recent meeting. *William F. MacDonald*, named president of the company, will continue temporarily to retain his present office as treasurer. Major *Aaron E. Carpenter* voluntarily relinquished the presidency and was elected chairman of the Board of Directors. *Charles P. Stocke*, assistant secretary, and *Marie A. Healey*, assistant treasurer, were both re-elected to their respective offices.

Van H. Leichliter has been named assistant vice president-operations of the American Steel & Wire Co., a United States Steel Corp. subsidiary. Previously general superintendent of the company's South Works in Worcester, he will now be located in the main office in Cleveland, Ohio.

The appointment of *Carl A. Day* as head of manufacturing at Bausch & Lomb Optical Co. has been announced. Mr. Day was formerly works manager of the company.

Charles B. Belknap, coordinator of research for the Owens-Illinois Glass Co., was recently elected to the Board of Directors of Arthur D. Little, Inc. At the same meeting, *Howard J. Billings* was named treasurer, to succeed *Henry G. Powning*. Mr. Billings will also be in charge of the company's non-technical internal operations, previously

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the responsibility of *T. L. Wheeler,* vice president, who plans to retire shortly.

The Steel Improvement & Forge Co. has promoted *Walter A. Frazee* to senior vice president and *Aubrey H. Milnes,* chief engineer, to vice president in charge of engineering and sales.

Sidney Rolle, assistant manager of the Scomet Engineering Co., expects to depart this month for England and the Continent, where he will visit metallurgical plants interested in large capacity induction furnaces for melting nonferrous metals.

The appointment of *Roy D. Haworth, Jr.* as manager of product development of the Carbide Alloys Div. of Allegheny Ludlum Steel Corp. has been announced. Mr. Haworth, formerly employed by Armour Research Foundation as supervisor of abrasion research, will be located at the Division's headquarters and plant at Ferndale, Detroit, Mich.

Edmund D. Haigler has joined Fischer & Porter Co., where he will work on special customer engineering problems. Mr. Haigler was previously manager of the Foxboro Co., and recently completed a 2-year survey of the mining, milling and smelting industries.

The retirement of *V. A. Lowinger* from the chairmanship of the International Tin Research & Development Council, which controls the Tin Research Institute, has been announced. His successor is *G. F. A. Burgess,* a joint managing director of the British Metal Corp., Ltd.

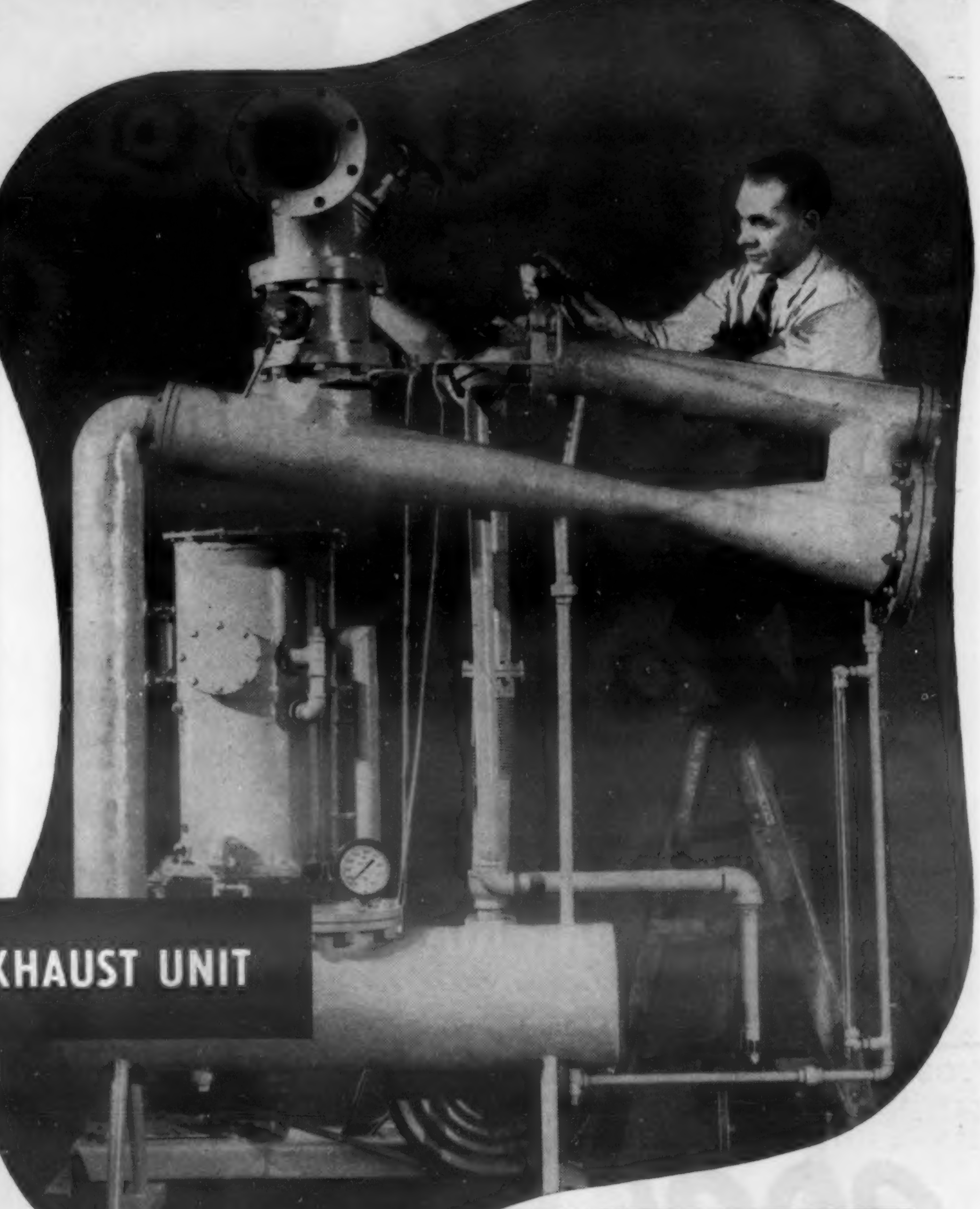
John H. Smith was recently elected president of General Electric X-Ray Corp., to succeed *John H. Clough,* who became chairman of the Board of Directors. Mr. Smith, formerly executive vice president, is also president and Mr. Clough chairman of the board of General Electric Medical Products Co., a subsidiary of General Electric X-Ray. Mr. Clough relinquished the presidency in order to concentrate on coordinating basic research carried on at G.E.'s Research Laboratory in Schenectady, N. Y.

Haynes Stellite Div., Union Carbide & Carbon Corp., has appointed *William B. McFerrin* division executive vice president and *Robert M. Briney* division vice president in charge of Wrought Alloy Products. Mr. McFerrin was assistant manager of development, Electro Metallurgical Div., U.C.C., and Mr. Briney was manager of the Development Div., Union Carbide & Carbon Research Laboratories, Inc.

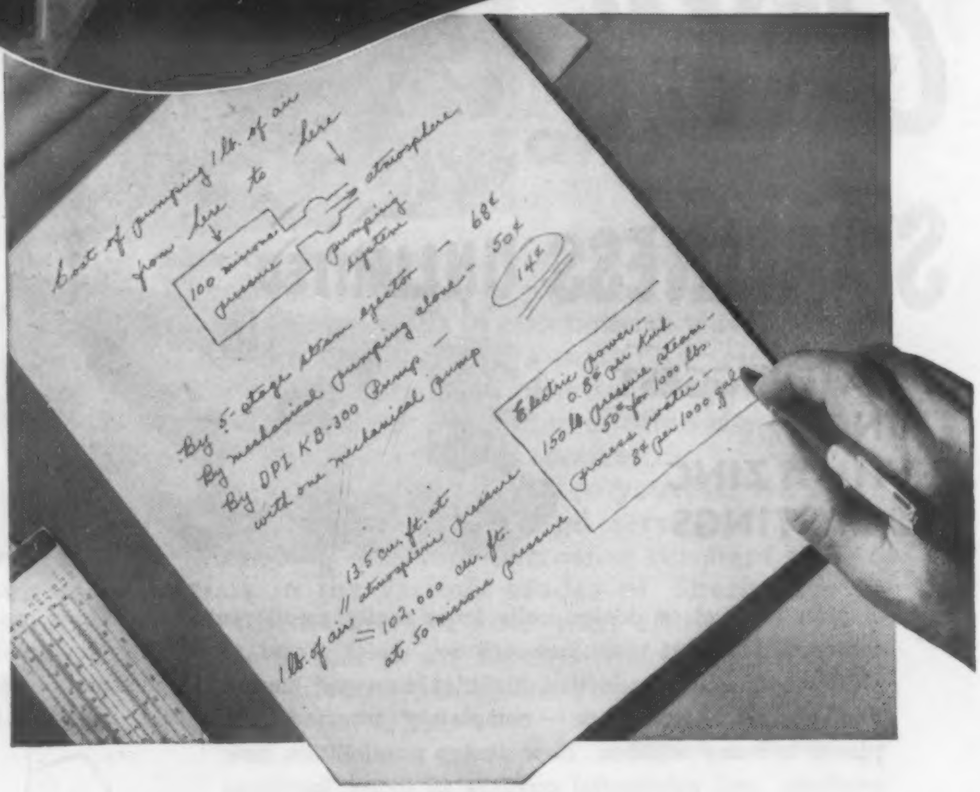
Curtner B. Akin has joined National Electric Products Corp. as manager of its Mechanical Tubing Dept. He was formerly associated with the Service Steel Co.

The Aluminum Co. of America has appointed *John M. Mitchell* manager of its Export Div., and *G. B. D. Peterson* sales

Another DPi High Vacuum "Packaged" Unit that cuts pumping costs



...THE NEW KB-300 EXHAUST UNIT



SPECIFICALLY designed to handle large volumes of gas, this unit provides:

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manager of the Division's New York office. Mr. Mitchell, in recent years in charge of Alcoa sales in Mexico, will make his headquarters in Pittsburgh. Mr. Peterson previously was sales representative for the Aluminum Co. in York, Pa.

Arthur G. Gibbs, well-known electrochemist and inventor, died recently after a brief illness. Mr. Gibbs had been associated with the Pennsylvania Salt Manufacturing Co. for 43 years until his retirement in 1946. He was most widely known for the development of the Gibbs cell for the electrolytic production of chlorine, caustic soda and hydrogen from common salt brine.

The Titan Metal Manufacturing Co. has announced the death of *William Philip Sieg,* founder and former president of the company.

Colonel *William Watts Rose,* formerly executive vice president of the Gray Iron Founders' Society, died after several years of severe illness.

News of Companies

John D. Shaw, Walter V. Knopp and Catherine L. Clark have announced the formation of *S-K-C Research Associates,* with laboratories located at 445 Fifth Ave., Paterson 4, N. J. They will offer research, technical consultation and development in powder metallurgy, process and plant design, and mechanical, chemical and metallurgical engineering.

The *Lewis Welding & Engineering Corp.,* Bedford, Ohio, has purchased the Euclid, Ohio, plant and equipment of the *Joy Manufacturing Co.,* Pittsburgh, Pa. The new plant will be organized as a separate manufacturing entity and will do machine work and machine assembly work as the *Breckenridge Machine Div.* of *Lewis Welding & Engineering Corp.* Lewis Welding will continue to handle Joy Manufacturing work at the newly-acquired plant on a contract basis until the Joy concern is prepared to absorb such work in its other factories.

Production of "Carborundum" silicon carbide has begun by the *Carborundum Co.* in a new plant adjacent to the Port of Vancouver Terminal, No. 2, Vancouver, Wash. J. L. Bergman is plant superintendent; A. C. Knapp, plant engineer; and E. E. Einhorn, office manager.

The Rolling Mill business of *Loewy Construction Co., Inc.* will in the future be operated as *Loewy Rolling Mill, Div.* of

News Digest

Hydropress, Inc. Offices are located at 570 Lexington Ave., New York City.

The purchase of a building adjoining its Cleveland plant, formerly owned by the Leece-Neville Co., has been announced by the *Osborn Manufacturing Co.* The Technical Dept. of the Osborn Brush Div. will be located in the new building, and will contain all machines, tools and laboratories needed to supply technical service on brush applications and similar problems for any industry making use of power brushing.

Philips Laboratories, Inc., New York 17, N. Y., has granted to the *Stackpole Carbon Co.*, St. Mary's, Pa., a license under a number of patents pertaining to magnetic ferrites and the manufacture thereof.

Entry into the manufacturing field has been announced by *Houghton Laboratories, Inc.*, Olean, N. Y. Formerly an industrial consultant on protective coatings and corrosion control, Houghton Laboratories are now manufacturing a series of new anti-corrosive metal primers and surface coatings, as well as a new plastic material called Hysol 6000.

The purchase of the entire business and assets of *Tincher Products Co.*, Chicago, Ill., by *Ideal Industries, Inc.*, Sycamore, Ill., has been announced. The company will continue to operate under the name Tincher Products Co., but as a wholly-owned subsidiary of Ideal Industries. A. B. Tincher, originator of the Tincher Process for sealing porosity in castings, will continue with the company in an active sales-engineering capacity.

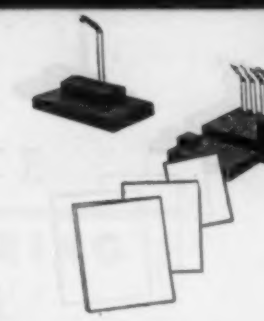
The *Precision Tube Co.*, Philadelphia, Pa., recently appointed two new sales representatives to handle their line of small seamless mechanical tubing. They are *Otto Bussenius & Co.*, 80 E. Jackson Blvd., Chicago 4, Ill., and *C. E. Anderson Co.*, 4500 Euclid Ave., Cleveland 3, Ohio.

Under terms of a working agreement with the *Hungerford Plastics Corp.*, Murray Hill, N. J., the *Ohio Rubber Co.*, Willoughby, Ohio, has expanded its services to include flexible vinyl and other thermoplastic materials used for a wide diversity of component parts and complete products. At the same time, Ohio Rubber acquired exclusive sales rights for the Hungerford "Flex-Grip."

The *Prozite Co.*, a recently formed Michigan corporation, has appointed *Gerity-Michigan Corp.*, Adrian, Mich., as exclusive national sales agent for its new line of buffing and polishing compositions.

Completion of a modern new water treatment plant to purify waste water from its steel mills along the Schuylkill River has been announced by the *Alan Wood*

(*Continued on page 158*)



MANUFACTURERS' LITERATURE

Materials

Iron • Steel

Screw Stock. Carnegie-Illinois Steel Corp., 8 pages, illustrated, No. ADV-18703. Performance data on MX steel, claimed to be today's fastest cutting Bessemer screw stock. Parts made from this steel cost less per unit and have better appearance than similar parts made from B-1113. (1)

Nodular Iron. Cerium Metals Corp., 12 pages. Some practical details on the production of nodular cast irons through addition of cerium to molten cast iron immediately before casting—a British-developed process. (2)

High-Speed Steels. Climax Molybdenum Co. Performance reports show how molybdenum high-speed steels, which harden at lower temperatures than tungsten tool grades, can save money in production. (3)

Steel Tubing. Peter A. Frasse & Co., Inc., 12 pages, illustrated. Data on machinability of seamless mechanical tubing. Includes practical recommendations for tool design. (4)

Iron Powders. General Aniline & Film Corp., 14 pages, illustrated. Chemical composition, particle size and density, electromagnetic constants and molding pressures for Carbonyl Iron Powders used in many electronic devices, including most of the television and radio receivers manufactured in this country. (5)

Nickel-Containing Materials. International Nickel Co., Inc., 32 pages, illustrated. Detailed survey of use of nickel-containing materials in tractors and farm implements. Useful information on materials problems faced in this industry. (6)

Abrasion-Resistant Alloy. Jones & Laughlin Steel Corp., 36 pages, illustrated, No. AD155. Case histories showing use of Jalloy, an alloy steel having high resistance to abrasion and impact, in mining, quarrying, and earthmoving industries. Also includes complete technical data. (7)

Iron Castings. Meehanite Metal Corp., 4 pages, illustrated, No. 32. Reviewed previously. Detailed tabular summary of physical properties of Meehanite high-quality gray iron castings. (8)

Spring Steels. Sandvik Steel, Inc., 111 Eighth Ave., New York 11, N. Y., 32 pages, illustrated. Free when requested on company letterhead. Catalog lists 785 different sizes of cold-rolled strip steels. Useful reference tables on weights, gages and hardness and temperature conversion included.

Bright Annealed Stainless. Wallingford Steel Co., 2 pages plus sample, illustrated. Data sheet on this company's 18:8 bright annealed stainless strip, accompanied by metal sample. (9)

Nonferrous Metals

Riveting Aluminum. Aluminum Co. of America, 64 pages, illustrated. Comprehensive book on riveting aluminum includes information on strength and proportions of joints, driving methods, selection of the rivet alloy, protection of joints, aircraft riveting, and other topics, in addition to much tabular material. (10)

Bronze Bars. American Crucible Products Co., 6 pages, illustrated. Lists sizes and approximate weights of Promet cored and solid bronze bars. Physical properties and advantages also given. (11)

Beryllium-Copper Strip. Beryllium Corp., 4 pages, No. 12. How to order beryllium-copper strip. Describes alloy, condition and temper, and gives mill sizes and mechanical and electrical properties. (12)

Low Melting Alloys. Cerro de Pasco Copper Corp., 40 Wall St., New York 5, N. Y. Loose-leaf binder and informative engineering literature on Cerro (low-temperature melting) alloys and special methods of application which have been useful in many phases of manufacturing. Free when requested on company letterhead.

Aluminum Casting Alloys. Federated Metals Div. of American Smelting & Refining Co., 40 pages, illustrated. Tabulates properties of 45 sand, permanent mold and die casting aluminum alloys. Also covers related metallurgy and foundry practice. (13)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on page 155.

Bronze Bars. National Bearing Div. of American Brake Shoe Co., 6 pages, illustrated. Catalog gives sizes and approximate weights of as-cast and machined cored and solid bars of N-B-M "Tiger" Bronze. Properties and advantages cited. (14)

Nonmetallic Materials

Pattern Plastic. A. R. D. Corp., 8 pages, illustrated. Prices, procedure and performance data for this company's Ard-Lustrex 15K, a stable pattern plastic for precision casting. (15)

Ceramics. American Lava Corp., 32 pages, illustrated, No. 444. Characteristics and applications of AlSiMag technical ceramics. Pictures many different forms produced and lists detailed properties for those grades most frequently used. (16)

Felt Gasketing. Anchor Packing Co., 4 pages, illustrated. Advantages offered by Chrome-Lock, an adhesive-backed, impregnated felt which is claimed to have cut application man-hours and overall gasketing costs over 50%. (17)

Resin-Glass Material. Apex Non-Ferrous Foundry, Div. of Apex Electrical Manufacturing Co., 2 pages, illustrated, *Apex Data Sheet*, Vol. 1, No. 9. Describes new engineering material, made of Fiberglas and several resins, which expands design limitations imposed by sheet metal stamping and casting methods. (18)

Plastisols. American Anode, Inc., 5 pages, No. A-8. Data sheets on American Resin Paste Plastisols for dip coating, spread coating, casting, slush molding, etc. Physical properties, applications and details of processing methods given. (19)

Plastics. Bakelite Div. of Union Carbide & Carbon Corp., 32 pages, illustrated, *Bakelite in Review*, Vol. 21, No. 4. Reviews four decades of progress in plastics industry with emphasis on Bakelite and Vinylite. Six additional articles. (20)

Plastics. Continental-Diamond Fibre Co., 30 pages, illustrated. Comprehensive technical information on Dilecto and Celoron laminating thermosetting plastics. Properties, grades, forms, applications, and fabricating procedures. (21)

Plywood. Douglas Fir Plywood Assn., 20 pages, illustrated. Physical properties, advantages and applications of exterior and interior grades of Douglas fir plywood. In-

MANUFACTURERS' LITERATURE

cludes joining and finishing information. (22)

Plastics. Monsanto Chemical Co., Plastics Div. Reviewed previously. Describes properties of this company's Lustrex styrene and other plastics. (23)

Plastics. Plaskon Div. of Libbey-Owens-Ford Glass Co., 4 pages, illustrated. Lists six advantages offered by Plaskon Alkyd plastic. Discusses application of this material in construction of magnetic starters. (24)

Plastic Packing. Raybestos-Manhattan, Inc., 4 pages, illustrated, No. A-941. Lists seven advantages of "Versi-pak," a non-jacketed plastic packing for general industrial use at pressures up to 600 psi. and temperatures up to 350 F or higher. (25)

Plastics and Rubber Application. Foster D. Snell, Inc. Folder explains this organization's facilities for determining suitability of rubber or plastics for particular application. Service includes testing of compounds, manufacturing methods and design. (26)

Felt. Western Felt Works, 32 pages, illustrated. History of manufacture and uses of felt, including brief description of present-day methods and applications. (27)

Industrial Plastic. Westinghouse Electric Corp., 36 pages, illustrated. Mechanical, electrical and chemical properties of Micarta, an industrial plastic, plus grade selection table for laminated and molded forms. Applications and advantages discussed. (28)

Parts • Forms

Alloyed Iron Castings. Advance Foundry Co., 8 pages. illustrated. Pictures many different applications of Strenes Metal, a series of alloyed, abrasion-resistant irons cast by this company. (29)

Magnesium Parts. Brooks & Perkins, Inc., 4 pages, illustrated. Describes complete facilities for production of fabricated parts or assemblies of magnesium. Table of properties of magnesium alloys included. (30)

Die Castings. Doehler-Jarvis Corp., 4 pages, illustrated. Reviewed previously. Advantages of the die-cast aluminum automobile door panel developed by this company. Discusses possible future applications of large die castings. (31)

Forgings. Drop Forging Assn., 60 pages, illustrated. Reviewed previously. Describes metal quality as developed in forgings formed in closed impression dies. Production techniques and economic advantages of forging given. (32)

Electrical Contacts. Fansteel Metallurgical Corp., 36 pages, illustrated. Fundamental notes on contact design and properties, advantages and principal uses of Fansteel electrical contact grades. Also discusses assembly methods, including riveting, spinning, upsetting, spot and projection welding, and brazing. (33)

Iron and Steel Castings. Hunt-Spiller Manufacturing Corp., 383 Dorchester Ave., South Boston 27, Mass., 24 pages, illustrated. Free when requested on company letterhead. Comprehensive metallurgical information on this company's cast Gun Iron, High Test Iron, high-carbon irons, austenitic irons, Carbon-Moly Steel and other irons and steels.

Bronze Bearings. Johnson Bronze Co., 16 pages, diagrams, No. L-5. Condensed catalog of Ledaloyl self-lubricating bronze bearings produced by powder metallurgy methods. Lists parts most in demand and immediately available from stock. (35)

Rubber Parts. Lavelle Rubber Co., 44 pages, illustrated, No. MS 46. Catalog of standard molded, extruded, lathe cut and punched rubber products. Helpful information on selection of type of rubber and manufacturing process for different fields of application. (36)

Low Alloy Steel Castings. Lebanon Steel Foundry, 4 pages. Reference chart on specification designations, analyses, physical properties and heat treatments for 15 carbon and low alloy steels cast by this company for a wide range of applications. (37)

Cold-Drawn Shapes and Shells. Linde Air Products Co., 2 pages. Reviewed previously. Discusses types of Prest-O-Lite cold-drawn shapes and shells which can be supplied, including materials and dimensional ranges. (38)

Metal - Wood Combinations. Met - L - Wood Corp., 12 pages, illustrated. Advantages, types, sizes, fabrication, construction details and applications of this company's metal-wood combinations, supplied either in sheet or fabricated form. (39)

Investment Castings. Microcast Div. of Austenal Laboratories, Inc., 2 pages, illustrated. Reviewed previously. Shows typical parts made of high-temperature, difficult-to-machine alloys by precision investment casting. (40)

Permanent Mold Castings. Non-Ferrous Permanent-Mold, Inc., 2 pages, illustrated. Explains how permanent mold casting of copper-base alloys can cut casting and finishing costs. (41)

Precision Castings. Ohio Precision Castings, Inc., 12 pages, illustrated. Series of application reports showing how this company's precision plaster mold castings have been used by several manufacturers to achieve close tolerances and smooth surfaces as well as economy. (42)

Textured Metals. Rigidized Metals Corp., 4 pages, illustrated, No. 1a/25. Reviewed previously. Characteristics of rigidized ferrous and nonferrous metals, available in strip and sheet, solid or perforated. How texturing reduces weight and cost by increasing rigidity and strength. (43)

Inorganic Plastic Moldings. Rostone Corp., 6 pages, No. 100. Reviewed previously. Data on general characteristics of Rosite inorganic plastic moldings. Recommends moldings for various electrical insulation purposes. (44)

Industrial Mainsprings. Sandsteel Spring Co., Inc. Folder on this company's facilities for designing and manufacturing flat mainsprings for industrial purposes. (45)

Steel Castings. Steel Founders' Society of America, 34 pages plus 13- by 20½-in. chart, illustrated. Reviewed previously. Numerous photographs show applications of steel castings in varied fields. Chart classifies general engineering types of castings according to tensile strengths and gives typical properties. (46)

Centrifugal Casting. Tempil Corp., 1 page, *Tempil Topics*, Vol. 5, No. 1. Brief, helpful summary of the process of centrifugal casting and its applications. (47)

Powdered Metal Parts. Wel-Met Co., 16 pages, illustrated, No. 104. Discusses relative advantages and limitations of powder metallurgy for producing parts. Covers physical properties, design factors and typical designs. (48)

Coatings • Finishes

Colloidal Graphite. Acheson Colloids Corp., 4 pages, illustrated, No. 431. Explains how metals, plastics and other materials can be coated or impregnated with "Dag" colloidal graphite to impart to these materials the properties of graphite, including greater lubrication, electrical conductivity, etc. (49)

Protective Coatings. Atlas Mineral Products Co., 8 pages, illustrated, No. 7-1. Information on Zerok, Ampuar, Atlastic, Koraloy and Alkaloy coatings for protection against corrosive fumes or splash on steel. (50)

Zinc and Steel Finishes. Azed, Inc., 46 pages. Series of technical bulletins on this company's products for protecting and decorating zinc or steel surfaces. Detailed data on finish and plate characteristics plus operating conditions. (51)

Protective Coatings. Bisonite Co., Inc., 14 pages. Series of data sheets on Bisonite "M" plastic coating for protecting metal surfaces against corrosion. Properties, uses, surface preparation, application and prices. (52)

Metal Primer. Dampney Co. of America, 2 pages, No. 1550. Data sheet on Dampney Metal Primer, and undercoating designed especially for metal scheduled for underwater service. (53)

Strippable Coating. E. F. Houghton & Co., 1 page. Data sheet on Houghto-Kote Cold Strip, an improved strippable vinylite plastic coating for metals. Properties, applications, advantages and spray instructions. (54)

Metallizing. Metallizing Engineering Co., Inc., 8 pages, illustrated, No. 62. Reviewed previously. Describes variety of iron and steel equipment which was metallized with

JOHNSON SLEEVE BEARING DATA — Bearing DESIGN — BRONZE SLEEVE BEARING DATA

Standard Tests for Sleeve Bearings-2

As pointed out in the preceding data sheet—"Standard Tests-1"—the prime reason for the large number of tests employed is simply to assure the user that he is getting the greatest bearing performance possible for his money. This is necessary in Sleeve Bearings not only because there are so many types of bearings available but also because it is possible to so design any type to secure all the necessary properties. Cast bronze is a good example. There are approximately one hundred separate and distinct alloys from which to choose. If plasticity and/or embeddability is a chief requirement the usual method is to increase the lead content. If greater hardness is required, the lead content is lowered, then tin, or nickel, or manganese, for instance, is increased.

One of the chief points to remember in specifying sleeve bearings is that they can be "tailor-made" to suit practically any application. The only requirement is that we first determine all of the pertinent operating factors.

Johnson Bronze Alloy No.	PHYSICAL PROPERTIES			
	(1) Wear Rate (dry)	(2) Coefficient of Friction (dry)	(3) Izod Notch Toughness	(4) Resistance to Pounding
19	0.24	0.16	3.4	54
25	0.36	0.14	5.2	22
27	0.32	0.19	4.4	63
29	0.35	0.16	5.6	40
51	0.63	0.25	8.3	81
53	0.62	0.26	8.5	86
55	0.53	0.29	3.9	109
66	0.50	0.19	8.4	20
71	0.64	0.18	12.1	20
72	0.41	0.19	8.6	38

A typical listing and comparison of various popular, cast bronze bearing alloys.

Resistance to Fatigue

This is the ability of the bearing material to withstand shocks and loads without deterioration or fracture. It is particularly valuable in testing bearings for internal combustion engines with rapidly alternating stresses on bimetal bearings such as steel backed, babbitt or bronze lined.

Izod Notch Toughness

This determines the amount of energy in foot pounds required to break a specimen. The specimen is notched and the energy required to fracture in a single blow indicates the toughness.

Resistance to Wear

This test determines the physical ability to resist destruction of two surfaces rubbing together without lubrication. The results are usually tabulated in the loss of weight in grams per 10,000 revolutions.

Resistance to Pounding

This is determined by establishing the number of blows of a hammer weighing 7.5 pounds, falling 2 inches, are required to deform the specimen 5%.

Coefficient of Friction

This test in bearing material is always computed on a "dry" basis, or a set up in which no lubricant of any kind is used. It is usually determined on an Amsler wear test machine.

Thermal-Conductivity

Thermal-conductivity is the ability of a bearing or bearing material to dissipate heat. It is a determination of the B.T.U.'s, per unit of time that will move through the material.

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Engineering Service

Johnson Bronze offers manufacturers of all types of equipment a complete engineering and metallurgical service. We can help you determine the exact type of bearing that will give you the greatest amount of service for the longest period of time. We can show you how to design your bearings so that they can be produced in the most economical manner. As we manufacture all types of Sleeve Bearings, we base all of our recommendations on facts free from prejudice. Why not take full advantage of this free service?

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This bearing sheet data is but one of a series. You can get the complete set by writing to—

Johnson Bronze

SLEEVE BEARING HEADQUARTERS
769 S. MILL ST. • NEW CASTLE, PENNA.

News Digest

Steel Co., Conshohocken, Pa. This plant is the first of its type to be built along the Schuylkill River to comply with the State's water purification program.

The *Wallingford Steel Co.*, Wallingford, Conn., has announced the addition of a new 2-stand, 4-high tandem mill, manufactured by *United Engineering & Foundry Co.*, Pittsburgh, Pa. Used in the breakdown of stainless and carbon steel, it is said to reduce strip gage by as much as 40% in a single pass.

Better Finishes & Coatings, Inc., Newark 5, N. J., is now shipping Chromic Acid Flake, Technical Grade, produced in newly installed electrochemical equipment at its Newark plant.

News of Societies

The *American Iron & Steel Institute* elected two new directors to fill existing vacancies. John N. Marshall, chairman of the Granite City Steel Co., succeeds the late Hayward Niedringhaus. And E. L. Clair, president of Interlake Iron Corp., assumes the vacancy resulting from the resignation of Leigh Willard.

The appointment of Charles Lukens Huston, Jr. to the board of trustees of *Drexel Institute of Technology* has been announced. Mr. Huston is president of the Lukens Steel Co.

Columbia University's Dept. of Chemical Engineering is conducting basic research in electroplating under an annual $1700 grant from the *American Electroplaters' Society*. The study is a cooperative research project of the metal finishing industry. The grant provides for a $1200 fellowship and an additional stipend of $500 for the department, to support the research. Edward B. Saubestre, Elmhurst, N. Y., is the first holder of the fellowship.

Dr. Francis C. Frary, director of research for the Aluminum Co. of America, has been awarded the James Douglas Metallurgical Medal for 1950 by the *American Institute of Mining & Metallurgical Engineers*. The Award was presented "for distinguished achievement in science and contribution to society by broadening the field of knowledge in all phases of the aluminum industry and for his notable success in directing a vast research project in this industry".

News Digest

The *University of Washington* is offering five fellowships in its School of Mineral Engineering for research in coal and nonmetallics, in cooperation with the United States Bureau of Mines. Fellows begin their duties on July 1 or Sept. 1, and continue for 12 months, with payments made at the end of each month amounting to $1320 for the year. The fellowships are open to graduates of universities and technical colleges who are qualified to undertake investigations of research character. Applications, to be passed upon early in May, should be submitted to Drury A. Pifer, Director, School of Mineral Engineering, University of Washington, Seattle 5, Wash. In addition to these fellowships, the University also offers an Edward Orton, Jr. Fellowship in Ceramic Engineering, and several Engineering Experiment Station Fellowships in Metallurgy and Ceramics. All carry a stipend of $110 per month with free tuition.

A $4000 research grant has been awarded to Dr. Max M. Frocht by the Research Corporation for fundamental study in three-dimensional photoelastic stress analysis. Dr. Frocht is a research professor of mechanics at the *Illinois Institute of Technology.*

The Dept. of Industrial Engineering of *Columbia University* has announced that it will conduct a 5-day conference on the Costs, Budgeting and Economics of Industrial Research from June 12 to June 16, 1950. Additional information may be obtained by writing to Professor David B. Hertz, Dept. of Industrial Engineering, 409 Engineering, Columbia University, New York 27, N. Y.

As part of its extensive research program, the *Steel Founders' Society of America* has initiated a special project directed to investigating and evaluating all known information on the removal of excess metal normally developed in the production of steel castings. Charles W. Briggs is the technical and research director of the project.

A $1300 research grant has been made to the *Illinois Institute of Technology* by the Allegheny Ludlum Steel Corp., for fundamental research in sigma phase formation in heat resisting steels. The study will be undertaken by Ahmed El Bindari, who received his master's degree in metallurgical engineering at Illinois Tech.

Donald L. Clark, Lockport, N. Y., has been appointed to fill the unfinished term of vice president of the *Electric Metal Makers Guild, Inc.,* made vacant by the resignation of E. J. Chelius.

The first doctor's degree in metallurgy ever awarded to a Brazilian has been granted by the *Carnegie Institute of Technology* to Luis Coelho Correa daSilva, now a doctor of science in metallurgical engineering. He has returned to Sao Paulo, where he will rejoin the staff of the Research Institute of the State of Sao Paulo.

Meetings and Expositions

AMERICAN CERAMIC SOCIETY, annual meeting. New York, N. Y. Apr. 24-26, 1950.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Process Industries Div. conference. Pittsburgh, Pa. Apr. 24-26, 1950.

AMERICAN MANAGEMENT ASSOCIATION, annual packaging exposition. Chicago, Ill. Apr. 24-27, 1950.

MACHINE TOOL ELECTRIFICATION FORUM. Sponsored by Westinghouse Electric Corp. Buffalo, N. Y. Apr. 25-26, 1950.

METAL POWDER ASSOCIATION, annual meeting and exhibit. Detroit, Mich. Apr. 25-26, 1950.

AMERICAN STEEL WAREHOUSE ASSOCIATION, annual meeting. Houston, Tex. Apr. 27-28, 1950.

METAL TREATING INSTITUTE, spring meeting. French Lick, Ind. May 1-3, 1950.

AMERICAN ELECTROPLATERS' SOCIETY, New England Regional meeting. Hartford, Conn. May 6, 1950.

LIQUIFIED PETROLEUM GAS ASSOCIATION, annual convention and trade show. Chicago, Ill. May 8-11, 1950.

AMERICAN FOUNDRYMEN'S SOCIETY, annual convention. Cleveland, Ohio. May 8-12, 1950.

AMERICAN TEXTILE MACHINERY EXHIBITION. Atlantic City, N. J. May 8-12, 1950.

INDUSTRIAL FURNACE MANUFACTURERS' ASSOCIATION, annual meeting. Hot Springs, Va. May 15-17, 1950.

NATIONAL DISTRICT HEATING ASSOCIATION, annual meeting. Asheville, N. C. May 23-26, 1950.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, spring meeting. Cleveland, Ohio. May 25-27, 1950.

CANADIAN INTERNATIONAL TRADE FAIR. Toronto, Canada. May 29-June 9, 1950.

AMERICAN SOCIETY FOR QUALITY CONTROL, national convention and Midwest conference. Milwaukee, Wis. June 1-2, 1950.

ELECTRIC METAL MAKERS GUILD, annual meeting. Springfield, Ohio. June 1-3, 1950.

SOCIETY OF AUTOMOTIVE ENGINEERS, summer meeting. French Lick, Ind. June 4-9, 1950.

AMERICAN GEAR MANUFACTURERS' ASSOCIATION, annual meeting. Hot Springs, Va. June 5-7, 1950.

NATIONAL ASSOCIATION OF PURCHASING AGENTS, annual convention. Cleveland, Ohio. June 12-14, 1950.

AMERICAN ELECTROPLATERS' SOCIETY, annual convention and international electrodeposition conference. Boston, Mass. June 12-15, 1950.

BOOK REVIEWS

Welding Handbook

WELDING HANDBOOK. THIRD EDITION. *Published by the American Welding Society, New York 18, N. Y., 1950. Cloth, 6 by 9 in., 1651 pages. Price $12.00.*

At long last the Third Edition of the Welding Handbook has come off the press. Four years work and the experience of more than 250 experts in the welding field have resulted in an up-to-date authoritative volume that should prove useful to anyone connected in any way with welding including engineers, designers, welding foremen and inspectors, manufacturers of welding equipment, and salesmen.

Twenty-seven chapters are devoted to the more than 30 welding and cutting processes. Information on each process covers the equipment used, the basic principles of operation, and the application of the process for different metals and different industrial applications.

Thirteen chapters contain information on the ferrous and nonferrous metals commonly welded, including their general properties, how to weld them with the different welding processes, and their use by different industries. Metals covered include iron, wrought iron, carbon and low-alloy steels, chromium steels, chromium-nickel steels, manganese steels, aluminum, magnesium, copper and nickel and their alloys, lead, zinc, clad steels and applied liners.

A group of eleven chapters cover design, material, workmanship and inspection requirements for industrial applications such as aircraft, bridges, buildings, railroads, storage tanks, pressure vessels and boilers, ships, automotive products, pipelines, industrial piping and machinery. Additional chapters are devoted to estimating costs, physics of welding, welding metallurgy, a dictionary of welding terms and definitions, general engineering tables for shop and office use, and welding standards, including welding symbols, filler metal specifications and standard tests for welds.

The Third Edition of the Welding Handbook contains several features which are intended to make it more useful for ready reference. The arrangement of the text in each group of chapters, *i.e.*, metals, processes and applications, is the same insofar as possible so that the reader might expect

Book Reviews

(continued)

to find the same type of information in the same relative location in each chapter within any one group. The more than 300 tables included contain reference data on welding procedures, properties of metals, properties of welds, code requirements and test results. A 69-page index makes it possible to readily find specific information and related information contained in the different chapters. Both the index and the text itself are extensively cross-referenced. Items in the index have been grouped by welding processes, by metals, by applications, and have been further grouped by the common divisions of engineering such as design, workmanship, inspection, etc. Each item is also separately listed in alphabetical order.

Other New Books

THE SOLIDIFICATION OF CASTINGS. *By R. W. Ruddle. Published by The Institute of Metals, London, S.W. 1, England, 1950. Cloth, 5½ by 8¾ in., 116 pages. Price $2.00.* The practical foundryman will find of considerable interest the methods described for the study of solidification rates of castings, and the results obtained by their use. This is No. 7 of the Institute of Metals' Monograph and Report Series.

PHENOMENA, ATOMS AND MOLECULES. *By Irving Langmuir. Published by Philosophical Library, New York 16, N. Y., 1950. Cloth 6¾ by 9¼ in., 436 pages. Price $10.00.* A selection of 20 papers published by the author since 1909 that attempt to interpret phenomena in terms of mechanisms or atomic and molecular interactions.

WELDING DICTIONARY. *Compiled and edited by R. N. Thompson and G. Haim. Published by the Louis Cassier Co., Ltd., London, S. E. 1, England, 1950. Distributed in the United States by British Books Centre, New York, N. Y., and in England by Iliffe & Sons, Ltd., London, S. E. 1. Cloth, 5 by 7½ in., 234 pages. Price 21s.* This dictionary has been divided into four parts—French, German, Spanish and English—the English part being treated as a key glossary with equivalents in the other three languages. Entries include, apart from terms which are specifically related to welding, many expressions pertaining to electrical and mechanical engineering and to metallurgy.

THE CHEMISTRY AND METALLURGY OF MISCELLANEOUS MATERIALS: THERMODYNAMICS. *Edited by Laurence L. Quill. Published by McGraw-Hill Co., New York 18, N. Y., 1950. Cloth 6¼ by 9¼ in., 329 pages. Price $3.00.* This book is No. IV-19B of the National Nuclear Energy Series containing results of surveys on the thermodynamic properties of the elements and several of their compounds, surveys on the crystal chemistry of many materials, papers on geochemistry and on the chemistry and metallurgy of beryllium and of the rare-earth elements, etc.—performed by the Manhattan Project Technical Section and the Atomic Energy Commission.

NON-FERROUS METAL MELTING AND CASTING OF INGOTS FOR WORKING. *Published by the Institute of Metals, London, S. W. 1, England, 1949. Cloth, 5¾ by 8¾ in., 168 pages. Price $2.50.* A symposium on the metallurgical aspects of nonferrous metal melting and casting of ingots for working, held in London during the annual meeting of the Institute, Mar. 31, 1949, is incorporated in this Monograph and Report Series No. 6.